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[FOURTH SERIES.]

ART. XLI.—*Some Conditions affecting Geyser Eruption;* by T. A. JAGGAR, JR., Cambridge, Mass.

1. *Introduction: the influence of hydrostatic pressure.*

BOTH field observation and experiment have contributed to our present knowledge of the physical causes of geyser eruption. The natural history of geyser regions has been summarized by Weed,* and the experimental work by Andreæ.† Weed concludes that geysers occur only in acid volcanic rocks, and along natural drainage lines where meteoric waters accumulate for discharge. The source of heat is conceived to be escaping hot vapors from slowly cooling lavas, the only known geysers occurring in regions of recent volcanic activity. New geysers originate by the opening of new waterways along fissure planes in the rock, and such new orifices of overflow are continually forming to compensate the diminution in activity of older vents. The cause of the intermittent spouting which distinguishes the typical geyser was originally stated by Bunsen‡; the boiling point of water rises with increased pressure, hence decreases from the lower end of a water-filled tube upward. If water of a lower stratum, nearly, but not quite, at the boiling point, be lifted by the entrance of steam from below to a level of less pressure and lower boiling point, "the heat which it possesses is in excess of that necessary to make it boil. This excess of heat is instantly applied to the generation of steam: the column is lifted higher and the water below is further relieved. More steam is generated, and from the middle downwards the mass suddenly bursts into ebullition. The water above, mixed with steam-clouds, is projected into the atmosphere. . . ."§

* School of Mines Quarterly, New York, 1890, vol. xi, No. 4, p. 289.
† Neues Jahrbuch für Min. Geol. und Pal., 1893, Bd. ii, p. 1.
‡ Tyndall: Heat as a Mode of Motion; Appleton, 1888, p. 168.
§ Tyndall, l. c., pp. 169–170.

The accuracy of Bunsen's theory was early confirmed by experiment and the only mechanism necessary to produce geyser eruption is a tube filled with water, open above and heated below. Many further experiments have been made, however, with a view to explaining the variations observed in the period and interval of geyser eruptions, the relative amount of steam and water, and the effect of artificial stimulants in hastening eruption. Andreæ's experiments were directed toward the imitation of Peale's* types, a classification based on the form of the basins and the relation of the periods of steam and water in the eruption. It is noteworthy that in most of these experiments, the apparatus recommended has an open basin above, which retains the water thrown out and permits it to *flow back* into the geyser tube.

In Peale's classification no mention is made of the nature of the geyser-spring during the interval of quiescence; in some cases there is continuous overflow or discharge, in others there is no overflow except during eruption. As it may be shown that this fact of the presence or absence of hydrostatic pressure at the geyser vent has an important bearing on the conditions of eruption, the writer would suggest a classification based on this very simple distinction; it is a singular fact that in the published descriptions of geysers this point has been frequently overlooked. If geyser waters represent meteoric drainage, they are affected by the laws of hydrostatic equilibrium. In such case a tube continuously overflowing is in a distinctly different class from one which throws off its waters to join the superficial drainage to the sea only during the period of its occasional or intermittent discharge. The first case is represented by such a geyser spring as "Excelsior," in the Yellowstone Park, a violently boiling cauldron in the hill slope, continually discharging vast volumes of water into the pond below, which in turn drains into the Firehole River; the Great Geyser of Iceland and the Rotomahana Geyser† of New Zealand are other types of the continually overflowing class. "Old Faithful" is the type of the second class: its waters may be seen in violent ebullition a few feet below the orifice of the vent, but overflow takes place only during eruption.

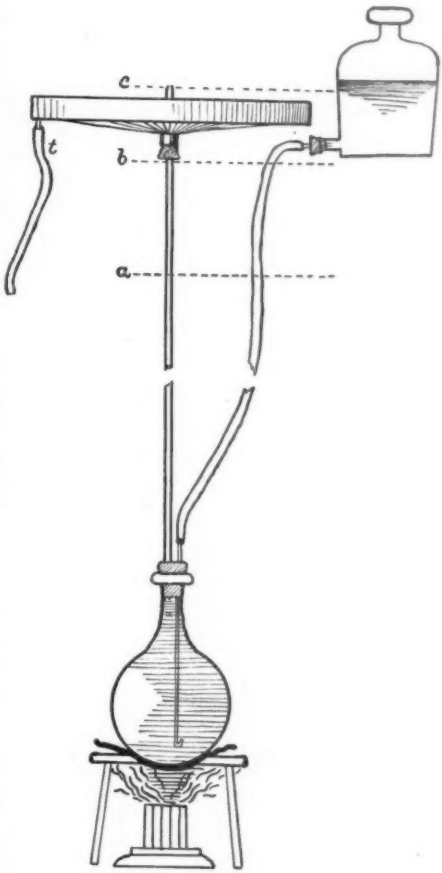
Any apparatus designed to imitate accurately either of these must be provided with a supply reservoir having subterranean connection with the geyser tube, by which water may siphon in to replace that discharged. Obviously this replacement takes place in nature: if the water, as asserted, is meteoric, and governed by the same laws that determine the loci of springs, the natural method of such replacement is by the action of gravity. In the case of Excelsior, this subterranean compensa-

* U. S. Geological Survey of the Territories, 1884, vol. xii, pt. 2.
† Destroyed by the Tarawera eruption in 1886.

tion is continuous; the effective head of water at the orifice of exit is fairly constant: in the case of Old Faithful the water-column is in equilibrium, and replacement occurs only after each eruption, when this equilibrium has been disturbed by the ejection of the column.

2. *Experimental Demonstration.*

A simple device to illustrate this process was described by G. Wiedemann* and mentioned by Andreæ.† Wiedemann made no geological comparisons, the apparatus having been constructed for class-room illustration in physics; and most of the geological experimenters have used back-flow apparatus, without supply reservoirs. The essential parts of Wiedemann's apparatus are a water-column heated below, and a supply-tube entering this column and connecting it with a reservoir of cooler, superficial waters. When the excess of steam generated has thrown out the main column, cooler water filters in through the supply tube, and fills the geyser tube to the level of the reservoir. For effective and regularly repeated geyser eruptions, the reservoir level must be maintained a little below the height of the mouth of the geyser tube.



The accompanying figure illustrates Wiedemann's apparatus, as it has been used by the writer. The dimensions are

* Wiedemann's Annalen, xv, 1882, p. 173. † l. c., p. 4.

as follows: capacity of each flask, one quart; length of main geyser tube 4 feet, diameter (outside) $\frac{5}{16}$ inches: diameter of basin 2 feet; the bottom flares funnel-wise from the center slightly, and is provided with a $\frac{1}{4}$ inch outlet tube *t*. The lower flask rests on a sheet of wire-netting over the flame of a four- or six-tube Bunsen burner, and the basin and reservoir bottle are supported above on a wooden frame. The basin is of zinc and may be raised or lowered so that the mouth of the geyser tube is flush with the bottom of the basin or raised above it as shown. The supply tube is recurved slightly at the bottom of the flask, so that the cold jets which siphon in from the reservoir will not be directed against the glass wall of the flask and break it. The reservoir bottle is connected by rubber tubing with the supply tube, so that the bottle may be freely raised or lowered to various levels indicated by the dotted lines *a*, *b* and *c*.

Experiment 1. "Old Faithful" Type.

When heat is applied below, the reservoir level being at *a*, after about 14 minutes an eruption takes place, characterized by violent ebullition in the flask below, ejection of the water-column to a height of about 4 feet and of a mixture of steam and water for a few seconds longer: then the water-level in the reservoir is seen to fall suddenly, a stream is seen to be flowing into the lower flask from the curved tip of the supply-tube, the cooling of the base of the column is accompanied by condensation of steam and downward suction, the water rises to level *a* again and a period of repose follows. It should be noted that if the level of the cooler water in the reservoir is at *a*, the expanded warmer water in the geyser tube is somewhat above *a*. The process described is repeated at regular intervals of about $1\frac{1}{2}$ minutes, the duration of each eruption being about 20 seconds. If the water in the reservoir be not renewed it gradually becomes warmer and the intervals are of shorter duration. In this case, or with the reservoir level somewhat higher, as at *b*, and the geyser mouth raised above the basin as shown in the figure, we have in miniature the conditions of "Old Faithful."

Experiment 2. "Excelsior" Type.

The conditions are altered if we raise the reservoir level to the point shown in the figure, namely, just above the height of the geyser mouth (*c*). In such case there is continuous overflow of the hot water, and if the outlet tube *t* be left open, this will continually flow off: this overflow must be constantly compensated at the supply tube by cooler water from the reser-

voir, so that the water in the flask never reaches the boiling point. If the water-level of the reservoir be maintained constant, this circulation will continue indefinitely, and in such case there will be a dome-shaped mass of hot water continually boiling up and overflowing at the geyser's mouth, as in the case of the Excelsior geyser. Now at this stage, if the water-level in the reservoir be allowed to sink under the drain upon it, it may fall to a level *six inches* below *c*, without interrupting the continuous overflow; in other words, it may fall back to the *b* level, and yet the geyser will continue to act as a boiling spring, without entering into an eruptive phase. The cause of this is to be found in the differential expansion of the water noted above, and a convectional upflow which acts as a driving power even against a reversed head, after overflow has once been established.* The overflow tube *t* may at this stage be led into the reservoir at the *b* level; this establishes a permanent circulation, the only loss being by evaporation. With the diminution in pressure if the level of the reservoir sinks, there is tendency toward diminished inflow of cooler water at the supply-tube: this implies rise in temperature of the water at the base of the geyser-column, which tends to augment both volumetric expansion and convectional velocity. Hence there is here a critical point where the hydrothermal and hydrostatic forces are in very delicate equilibrium; if the reservoir is lowered an inch, the overflow decreases, ebullition takes place below, and an eruption of extraordinary violence takes place. The same effect is at once produced by placing the glass stopper in the reservoir bottle and so checking the atmospheric pressure. When the mouth of the geyser-tube is flush with the bottom of the basin, an eruption may be induced by stopping the overflow tube *t* and permitting the water-level to rise in the basin, thus augmenting the pressure on the geyser column. Eruptions once started will continue intermittently, if the hydrostatic conditions are maintained constant: if, however, the water-level of the reservoir again rises to a point where continuous overflow is possible at the geyser's mouth, the eruptions will cease and a hot-spring phase will follow.

3. *Field application of the results of experiment.*

The two simple experiments described, when compared with the facts of nature, account for the most essential variations observed in the phenomena of geyser eruption. Both are methods of draining the reservoir: the one continuous, the other spasmodic. In the same way the geyser-springs drain

*Such convection currents gain no momentum without overflow, hence at the *a* level convection played no essential part in the phenomena observed.

off the superficial waters that accumulate from the abundant rainfall of the Yellowstone Plateau. The "Excelsior" cauldron is stated by Hague* to discharge constantly into the Firehole River 4400 gallons of boiling water per minute, "and there is no evidence that this amount has varied within the last two or three years (1887)." Weed† has estimated, on the moderate assumption that one third of the eruption-column of Old Faithful is water, that 3000 barrels are thrown off at each eruption. Here we have examples of continuous and spasmodic drainage methods, both sending their waters eventually to the Madison River, and resupplied from a local source.

The geyser basins are topographic hollows, which supply vents for the meteoric waters accumulated in fissures of the decomposed rhyolite. These waters are heated by vapors escaping from the only partially cooled deeper lavas, and are escaping in the form of springs and geysers. In the springs the overflow is occasioned by hydrostatic pressure: in the geysers it is permitted by occasional violent discharge. The transition from one phase to the other may readily be induced, as shown in Experiment 2, by very slight changes in the hydrostatic pressure, i. e. variations in the mean level of groundwater (Grundwasserspiegel), or in the local head for any specific case. The head may be modified at either the source (supply-reservoir) or the orifice of exit; head is diminished by lowering the reservoir through formation of new outlets or through decreased supply, or by building up a cone around the geyser tube. Conversely head may be increased by excessive supply (rainfall) at the reservoir, by clogging of outlets, or by the water finding a new vent at a lower level.

Bunsen stated that the transition from a geyser to a tranquil "Laug" like those frequently found in Iceland, would be occasioned by building up the geyser's bowl so as to raise the water-level, and thus "the water in the depths below, owing to the increased pressure, cannot attain its boiling point, and the eruptions of necessity cease."‡ While this may be true in special cases, we are inclined to believe that the efficient cause of cessation of eruption is generally to be found in an increase in the amount of continuous overflow, due either to new outlets (which may in many cases be subterranean), or increase in the local head. Probably many of the geysers whose eruption intervals are irregular, are in a condition of equilibrium near the critical point described in Experiment 2, so that very slight changes in the local pressure bring about eruption or cessation.

* Arnold Hague: Geol. History of the Yellowstone Nat'l Park, Trans. Am. Inst. of Min. Eng., vol. xvi, 1888.

† l. c.

‡ Tyndall, l. c.

It should be noted that exactly the reverse of Bunsen's prediction takes place in our apparatus; an overflowing spring, when confined by building up a basin about it (see page 327), finally ceases to overflow: convectional currents are thus checked, the boiling point is reached below and eruption begins.

On this hypothesis it will be seen that the source of heat is conceived to be fairly constant in the geyser region for like depths, while the variations in the springs are dependent wholly on delicately-balanced hydrostatic conditions; this seems consistent with the facts. A glance at the published atlas sheets (U. S. Geological Survey) of the Yellowstone Park will show that the three principal geyser basins are on drainage lines, and represent the sources of the Gibbon and Firehole Rivers, which unite to form the Madison. These basins are slight depressions in the rhyolite plateau, in a region of maximal rainfall "quite unlike that found in the adjacent country, as is shown by the meteorological records."* On the opposite side of the Continental Divide to the south, and of the Central Plateau on the east, the headwaters of the Snake and Yellowstone Rivers are represented by large lakes. No such lakes exist on the Madison side, the fissured rhyolite there holding its waters in hundreds of subterranean conduits, like a huge hot sponge, and this water overflows in the depressed areas in the form of sinter-building springs and geysers. The Norris and Upper Geyser Basins are about 7400 feet, the Lower Basin about 7200 feet above mean sea level; while the higher points on the divide rise to 8500 feet, affording drainage into these basins of 1100 feet fall. It is further significant that the highest of the geyser-basins is more than three hundred feet below the level of that enormous water-surface, the Yellowstone Lake, where hot springs still abound, and only a few miles of uninterrupted rhyolite sheets stretch between the geyser-basins and the lake.

With a fairly constant source of heat, and springs variously overflowing or confined according to the height of their orifices relative to the local source in each case, it would follow from the experiments that continuously overflowing geysers should exhibit greater irregularity in their eruptive periods and intervals than those so confined within their tubes that no discharge is possible except by incessant eruption. This is borne out in the types mentioned: Excelsior, the Great Geyser of Iceland, and Rotomahana are all known to have been quite irregular: while Old Faithful, the Constant, the Minute-man and the little Model, in the Yellowstone district, are all of the confined type and erupt with great regularity. Excelsior, now recognized as the greatest geyser in the world, was formerly called

* Hague, l. c.

the "Cliff cauldron" and was not known to be a geyser until 1878, when it was first seen in action: it continued to play at irregular intervals for four years and then ceased, resuming its eruptions in 1888. These were continued for only a short season, and since that time the vent has continuously discharged vast volumes of hot water, without explosive eruptions. There is evidently a delicate balance of adjustments between the hydrostatic and thermal forces which govern the actions of this torrent in the depths; it is possible that the level of the source is affected by exceptional variations in the mean annual rainfall. We should thus expect a period of eruption to follow within a year of a season of exceptional dryness, and consequent diminution of head.* In the case of Old Faithful regular eruptions have taken place about once an hour ever since its discovery in 1870: it is a very old vent, as indicated by the seventy feet of sinter which have been built into the walls of its conduit. It is probable that the water-column became confined by reason of the gradual erection of this enclosing shaft; where there may have been formerly continuous overflow, the column is now in equilibrium with its source, and is ejected only under accumulated steam pressure with rhythmic regularity. The tube fills to within a few feet of the orifice soon after each eruption; this implies percolation into the tube of cooler waters through lateral ducts: as it takes practically a uniform period, some sixty-five minutes, to heat this new column to a state of ebullition at the base, and has done so for twenty-eight years of human record, it is fair to conclude that the heat supply is constant.

While this coincidence of overflow with irregularity of eruption, and confinement with regularity, is in general accord with the facts of observation, it is not essential to the theory that every irregular geyser should visibly overflow at the surface or that every regular one should be enclosed. A non-eruptive spring may have subterranean outlets, and an overflowing one may play at quite regular intervals; in such a case ebullition in the depths will depend on the ratio of the amount of inflowing cooler water to the amount of heat supplied: in some cases, too, the overflow may be from a separate superficial source. Complications in the conduit system, such as steam-filled chambers, curved ducts and connections with other geysers, will readily account for the composite eruptions observed at some of the vents: a long steam period following the first eruption may be induced in our apparatus by partially reducing the

* It is noteworthy, though hardly relevant to this case, that in Virginia City, Montana, northwest of the Yellowstone Park, the mean annual rainfall for 1877, the year preceding the first observed eruptions of Excelsior, was much less than the average of the mean annual records for the next four years.

atmospheric pressure at the reservoir-bottle with the stopper: the same effect is produced by clamping the rubber supply tube and thus checking the inflow of cooler water. When a powerful geyser-spring passes from an eruptive phase to quiescence, or the reverse, there is probably a reflex effect on the level of the source, for the total volumetric discharge is probably usually less for the same period under thermal action alone, than when hydrostatic pressure is combined with convection. In other words, geyser eruption is probably not so effective a method of drainage as continuous overflow in certain cases; thus the eruptive phases of Excelsior may have induced a rise of level in the source, an increase of head, and a consequent return to a condition of violent overflow without eruption.

4. *Soaping Geysers.*

It has long been known that by artificially confining the steam in small-mouthed geysers of high surface temperature, eruption may be brought about prematurely. In Iceland the Strokr is thus stimulated by dumping into the neck of the funnel large pieces of turf. In the Yellowstone district, it has been found that a small amount of soap or lye added to the geyser water will frequently hasten eruption. This is explained by Hague* as due to the increased viscosity of the liquid. "Viscosity must tend to the retention of steam within the basin and . . . . explosive liberation must follow . . . . Viscosity in these hot springs must also tend to the formation of bubbles and foam when the steam rises to the surface, and this in turn aids to bring about the explosive action, followed by a relief of pressure, and thus to hasten the final and more powerful display." Graham,† as a result of experiments with an artificial geyser, agrees that viscosity has much to do with the confinement of the steam, but questions the influence of bubbles and foam.

Experiment 3. The effect of soap.

The apparatus was arranged to give regular eruptions as in Experiment 1, with the geyser-tube flush with the bottom of the basin and the water maintained about an inch deep in the basin without overflow. A small quantity of fine shavings of Ivory soap was thrown into the basin: these gradually dissolved and the milky solution was, after several eruptions, sucked into the flask below. The occasional steam-bubbles, which, in pure water, rise rapidly through the geyser-tube and

* Arnold Hague: Soaping Geysers, Trans. Amer. Inst. Min. Eng., vol. xvii, 1889, p. 546.

† This Journal, January, 1893, p. 54.

escape at the surface during the intervals between eruptions, were less numerous, very small, and slower in their upward movement through the soapy solution; after five or six eruptions it became evident that the intervals were somewhat shorter (averaging 1 min. 20–30 seconds instead of 1 min. 30–40 seconds) and the periods very noticeably longer (40–45 seconds instead of 20 seconds). The ebullition in the flask was more violent than in the case of pure water, and columns of fine bubbles accumulated in the geyser-tube, only to be ejected with a violent sputter and give place to a new accumulation. It was evident that these accumulated myriads of tiny steam bubbles, confined within the tube and adhering to the walls of the tube, formed a cushion opposing considerable resistance to pressure from below.

After the diffusion of the soapy solution had become general, the reservoir (and consequently the geyser-column) was lowered to the level *a*; the intervals were at once shortened to an average of about one minute, in consequence of the rapid accumulation at the surface of the column and *within the tube* of the cushion of steam bubbles. So resistant is this cushion, that as it grows by the addition of new bubbles rising from below, the water column is actually depressed, down to the neck of the flask; here a point is reached where the frictional resistance of the froth cushion and the hydrostatic pressure are balanced. A further accumulation of steam forces up the column of foam, release of pressure permits the water to burst into violent ebullition and an eruption takes place. From this it would appear that in those geysers where the tube is small, the growth of a cushion of steam soap-bubbles may play a very important part in accelerating the development of eruptive conditions.

Summary.

1. Geysers and boiling springs are subject to the laws of hydrostatic pressure, in common with other springs.

2. In a geyser-spring, overflow once established may be maintained by convection even against a reversed head; this leads to a critical point in the spring's mode of discharge.

3. In this condition, with a constant source of heat, very slight changes in the local head are sufficient to induce a change in the nature of a geyser-spring's mode of action. Such change in the head may be caused by variation in rainfall, by building up a sinter cone, by forcing new outlets at lower levels, or by clogging of old conduits.

4. Geyser basins afford drainage channels for meteoric waters. The drainage takes place by either continuous over-

flow (hot springs) or spasmodic eruption (geysers). Both types, as well as transitional forms, are represented in the Yellowstone Park.

5. In general, those geysers which are irregular in their eruptions have continuously overflowing vents; and the most regular geysers have confined waters, which overflow only during eruption. This is explained by the fact that the overflowing vents are under hydrostatic pressure, cooler water from lateral ducts is continually replacing that which flows off, and the ebullition necessary to produce eruption is thus prevented; eruption can only take place in the seasons of minimal inflow of cooler water, when the heat is in excess. Where the water is confined, on the other hand, and the supply of heat constant, cooler water rushes in only after each eruption, and a definite interval is required to bring it to the boiling point at the base of the column. Overflowing and confined springs should be distinguished in any description or classification of geysers.

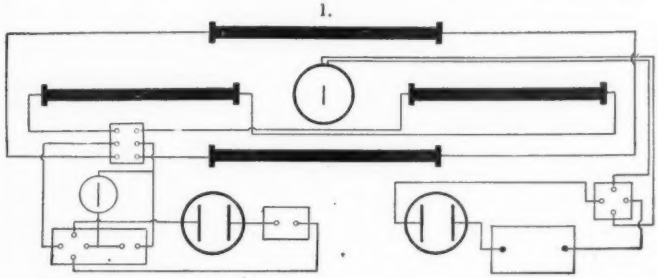
6. For the artificial stimulus of geyser eruption, an important effect of the bubble-forming alkalies, in small tubes, is the initial depression of the water-column by the growth of a confined cushion of minute steam bubbles. The release of pressure induced by the final ejection of the froth column causes eruption.

Art. XLII.—*On the Properties of Seasoned Magnets made of Self-Hardening Steel;* by B. O. Peirce.

In searching for a material of which to make a set of standard measuring magnets which should be as permanent as possible and have small temperature and induction coefficients, I have tested a large number of magnets made of some of the brands of self-hardening tool steel now in common use for lathe tools. It is obvious that self-hardening steel has certain disadvantages as compared with ordinary fine tool steel: it is not generally obtainable in the form of slender, polished, accurately cylindrical rods, it is extremely difficult to work while cold, and most magnets made of it are somewhat weaker than similar magnets made of the best drill rod.

My experiments seem to show that comparatively short seasoned magnets made of self-hardening steel have decidedly smaller induction coefficients than magnets of the same dimensions made of tool steel. The difference in the case of the temperature coefficients is much less, though the advantage appears to be on the side of the self-hardening steel. It is comparatively easy to get a long uniform rod of self-hardening steel and extremely difficult to make a very long slender rod of tool steel uniformly glass-hard and at the same time straight. The temperature and induction coefficients of long magnets of the two kinds of steel seem not to be very different.

Most of the experiments here recorded were made on pieces cut from cold rods of self-hardening steel by the help of a very thin elastic emery wheel, which did not unduly heat the material. Large rods of glass-hard tool steel cut under water



by the same wheel showed no disturbance of temper at the ends of the pieces. The susceptibilities of many of these specimens of self-hardening steel were then determined in an

induction bench (figure 1) before and after they had been exposed to steam at 100° C. for hours in the manner suggested by Messrs. Barus and Strouhal. The results given in Tables III and IV show that the long-continued heating did produce a slight "relaxation" of the metal.

The pieces of steel were then magnetized between the poles of a soft iron yoke in a large solenoid carrying a current of 25–35 amperes. The semi-permanent moments which they acquired in this way were, however, much reduced (as may be seen by comparing the figures given in columns 2 and 3 of Table V) by boiling them for a long time in water and thus seasoning them. I expected that a number of long, seasoned magnets of given dimensions made in this way would be more nearly alike than a set of similar magnets made of tool steel, in the case of which the difficulties of uniform hardening are so great; but in this I was disappointed. Occasional very abnormal specimens occurred. A magnet seemingly like its neighbors would show a very low moment and at the same time temperature and induction coefficients 30 per cent or more above the others, which would prove to be nearly alike. An attempt to remedy these defects by remagnetizing the steel failed. I have assumed that a normal magnet is characterized by a high magnetic moment and low temperature and induction coefficients, and, although I could not prove, as in the case of tool steel, that all abnormal magnets were either soft in places or cracked, I rejected all such without question.

The temperature coefficients* were determined in a piece of apparatus described by Mr. Arthur Durward in his paper "On the Temperature Coefficients of Certain Seasoned Hard-Steel Magnets." The magnet to be experimented upon was fixed firmly in a non-magnetic holder inside a non-magnetic tube so as to be in Gauss's A Position east of a mirror magnetometer. By the help of an elaborate system of pipes constructed by Mr. J. Connors of the staff of the Jefferson Laboratory, tap water, steam, or a stream of water from a bath-water heater at almost any desired constant temperature between 15° and 100°, could be sent through the tube surrounding the magnet. On the west of the magnetometer, so placed in Gauss's A Position as to bring the needle back into the meridian, was a short, seasoned, compensating magnet fixed within a wooden holder and completely shielded from sudden temperature changes. If M′ is the moment of the compensating magnet; α_0, the needle deflection which it would cause if the magnet to be

* G. Wiedemann, Pogg. Ann., 1852, 1858, 1864; Dufour, Arch. de Genève, 1857: Lamont, Handbuch d. Magnetismus, 1867; Barus and Strouhal, Bulletin of the U. S. Geological Survey. No. 14, 1885; F. Kohlrausch, Wied. Ann., 1884; Cancani, Atti Acc. Linc., 1887.

tested were away: M_0, the moment of the last named magnet at the temperature t_0, at which the adjustments have been made; and M, the moment of this magnet when, its temperature having become t, the needle is deflected through the angle α,

$$\frac{M_0 - M}{M_0} = \frac{\tan \alpha}{\tan \alpha_0}.$$

The strength of the field around the magnetometer needle could be modified at pleasure, and in this way great sensitiveness obtained. The change of moment caused by a change of temperature of a small fraction of a degree, even in the case of the shortest magnets used, could be easily measured when the center of the magnet was many times the length of the magnet away from the magnetometer.

If any one of my magnets which had not been heated above room temperatures for some time, was heated to 100° and then brought back to the room temperature, it did not immediately regain its original moment, and in the case of some magnets this temporary loss seemed to be greater than any which Mr. Durward noticed in the case of tool steel magnets. Upon reheating the magnet to 100°, there seemed to be little if any addition to this temporary loss, and the moment passed through a cycle when the temperature returned to its old value after going through any succession of changes. Whatever the previous history of a magnet had been, a sudden increase in temperature was accompanied by a sudden, not a gradually

TABLE I.

Results of observations on a seasoned magnet 8cm long made of Jessops Square Self-Hardening Tool Steel.
Dimensions of cross section, 0·96cm × 0·96cm.

Temperature.	Loss of magnetic moment in terms of the moment, M_0, at 7·7° C.
7·7	0·0000
12·0	0·0028
20·0	0·0087
30·0	0·0171
40·0	0·0259
50·0	0·0353
60·0	0·0448
70·0	0·0559
80·0	0·0683
90·0	0·0825
100·0	0·1016

TABLE II.

Results of observations on a seasoned magnet 6cm long made of Mushet Square Self-Hardening Tool Steel.
Dimensions of cross section, 0·96cm × 0·96cm.

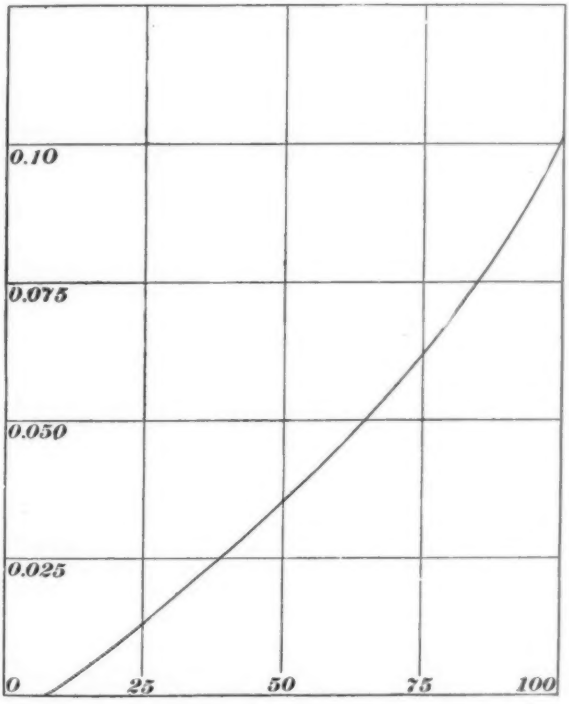
Temperature.	Loss of magnetic moment in terms of the moment, M_0, at 7·2° C.
7·2	0·0000
12·0	0·0048
20·0	0·0140
30·0	0·0275
40·0	0·0420
50·0	0·0580
60·0	0·0805

increasing, fall of moment and the rate of the fall per

degree increased with the temperature. If, therefore, a curve be plotted the abscissas of which give the temperatures and the ordinates the differences between the moment (M_0) of any magnet at some given lower temperature (t_0) and the moments (M) of the same magnet at these temperatures, this curve will be concave upward.

Tables I and II give the results of a series of observations made by Mr. C. G. Persons on two short, stout, magnets made of self-hardening steel, which are fairly representative. In figures 2 and 3, where these results are shown graphically, the temperatures are used as abscissas and the corresponding values of the ratio of $M_0 - M$ to M_0 as ordinates. It is worthy of

2.

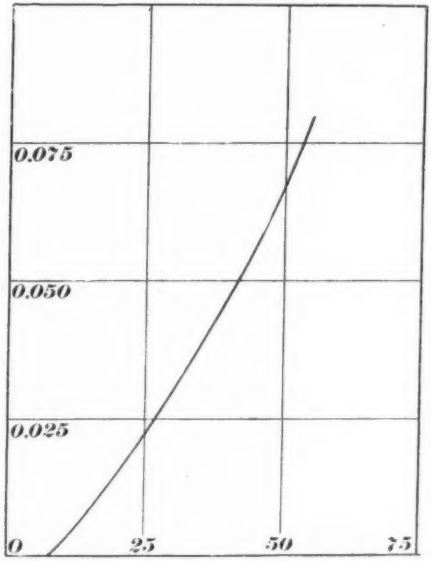


notice that these curves depart so widely from straight lines that the temperature coefficient, $-\frac{1}{M} \cdot \frac{dM}{dt}$, is in each case

about three times as great at 100° C. as at the temperature of the tap water.

Tables III, IV, and V show the results of a large number of measurements on magnets made of two well known brands of self-hardening steel. If the lengths of the magnets are used as abscissas and the corresponding numbers in the last two columns of each of these tables as ordinates, we get the curves represented in figures 4, 5, and 6. In the case of magnets made of ordinary fine tool steel, the differences between the temperature coefficients at low temperatures and at the temperatnre of boiling water, which are large when the magnets are

3.



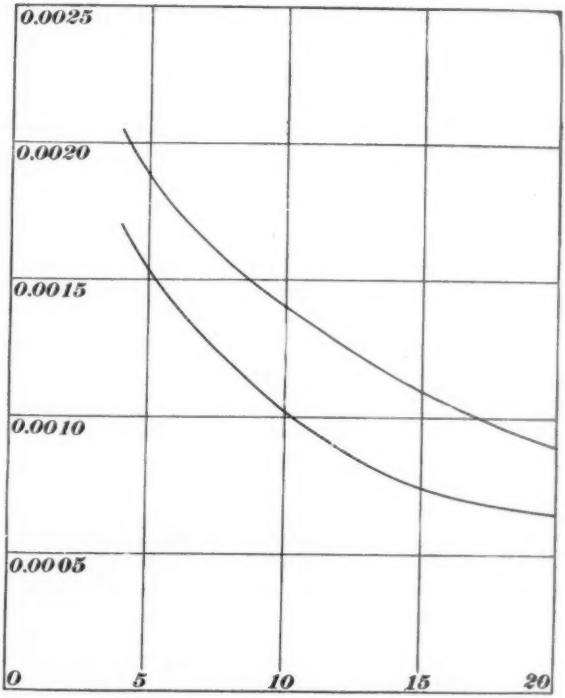
short, often become insignificant when they are relatively long. No such tendency is shown in the curves here printed. A portion of the upper curve in figure 6 which seems too nearly vertical, was drawn through points obtained by measuring a large number of magnets less than 4^{cm} long.

The work of Mr. Durward appears to show that whereas relatively long magnets made of fine tool steel generally have smaller temperature coefficients than relatively short ones, we cannot hope to reduce to zero the temperature coefficient of a magnet made of stout rod by lengthening it indefinitely. It

does not seem likely that a very long magnet made of the Jessops self-hardening steel, which I experimented on, would have a much lower temperature coefficient than the longest specimens I used.

The only very stout magnets with negative temperature coefficients that I have seen described are the comparatively weak ones made by Lamont of a kind of laminated steel and iron used in Russia. One of the advantages of very slender magnets, like those used so skillfully by Professor T. Gray, is that their temperature coefficients are comparatively small, as Cancani and others have shown. The relative loss of moment, when heated from the room temperature of 10° C. to 100° C.,

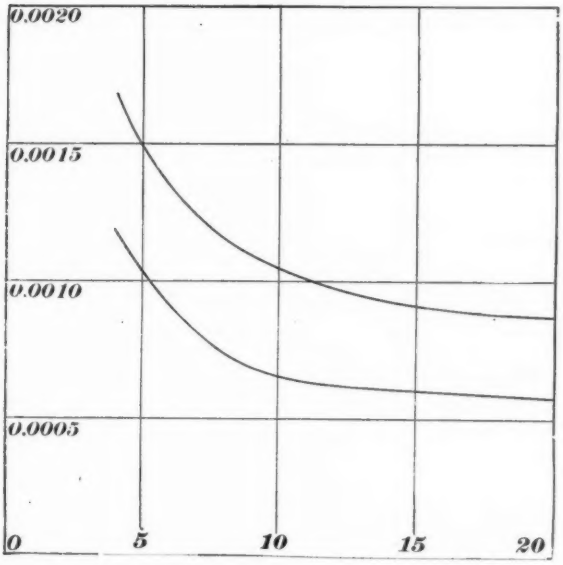
4.



of a number of very strong, seasoned magnets 10^{cm} long made of "Crescent Drill Rod" are shown in the following table. These results seem to point to small if not to negative coefficients in the case of very thin wire.

Diameter in centimeters.	$\frac{M_{10}-M_{100}}{M_{10}}$
0·33	0·00024
0·33	0·00022
0·33	0·00022
0·26	0·00015
0·23	0·00012
0·18	0·00010
0·18	0·00010

5.



Much smaller coefficients than those here indicated are often obtained. I have a seasoned magnet 10^{cm} long made of Crescent Drill Rod $2{\cdot}0^{mm}$ in diameter the moment of which appears to be constant between 10° C. and 100° C. The moment per gram of this magnet is 29·3 c. g. s. units. A somewhat stronger magnet made from a piece of the same rod has a small but unmistakably positive coefficient. I have been unable to procure any very slender pieces of self-hardening steel, but if we may judge by the trend of observations made on thick specimens, a thin wire of this steel would yield magnets with very small temperature coefficients.

6.

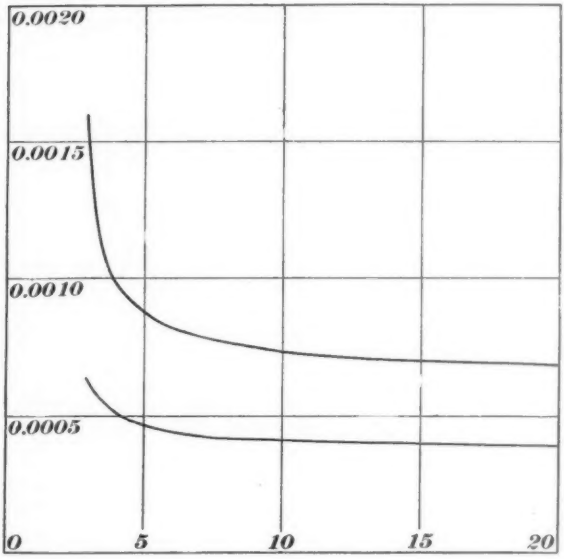


TABLE III.

Mushet's Square Self-Hardening Tool Steel.

Dimensions of cross section 0·96 × 0·96^{cm}. Wt. per centimeter of length, 7·9 grams

Length in centimeters.	Moment per gram of the magnetism induced in the specimen in the condition in which it was purchased, when placed lengthwise in a unit field.	Moment per gram of magnetism induced in the specimen after it had been long boiled when placed lengthwise in a unit field.	Approximate magnetic moment per gram of the seasoned magnet at 15° C., expressed in c. g. s. units.	Approximate ratio of the induced moment caused by unit field to the permanent moment in the case of the seasoned magnet.	Mean loss per degree of the magnetic moment when the magnet is heated from about 15° C. to 100° C. expressed in terms of the moment at the lower temperature.	Temperature coefficient of the seasoned magnet at 15° C.
4·0	0·08	0·08	5·0	0·016	0·00205	0·00170
6·0	0·11	0·11	8·0	0·014	0·00175	0·00140
8·0	0·12	0·13	10·5	0·012	0·00155	0·00119
10·0	0·13	0·14	13·0	0·011	0·00140	0·00101
12·0	0·14	0·15	15·5	0·010	0·00127	0·00087
14·0	0·15	0·16	18·0	0·009	0·00115	0·00077
16·0	0·16	0·17	21·0	0·008	0·00105	0·00071
18·0	0·16	0·17	23·5	0·007	0·00097	0·00067
20·0	0·17	0·18	26·0	0·007	0·00090	0·00065

TABLE IV.

Jessops Square, Self-Hardening Tool Steel.

Dimensions of cross section 0·96^{cm} × 0·96^{cm}. Wt. per centimeter of length, 7·9 grams.

Length in centimeters.	Moment per gram of the magnetism induced in a specimen, in the condition in which it was purchased, when placed in a unit field.	Moment per gram of magnetism induced in the specimen after it had been long boiled, when placed lengthwise in a unit field.	Approximate magnetic moment per gram of the seasoned magnet at 15° C., expressed in c. g. s. units.	Approximate ratio of the induced moment caused by unit field, to the permanent moment in the case of the seasoned magnet.	Mean loss per degree of the magnetic moment when the magnet was heated from about 15° C. to 100° C. expressed in terms of the moment at the lower temperature.	Temperature coefficient of the seasoned magnet at 15° C.
4·0	0·05	0·05	4·5	0·011	0·00170	0·00119
6·0	0·07	0·08	7·0	0·011	0·00135	0·00092
8·0	0·08	0·09	9·0	0·010	0·00116	0·00074
10·0	0·09	0·10	11·5	0·009	0·00107	0·00066
12·0	0·10	0·11	14 0	0·008	0·00098	0·00063
14·0	0·11	0·12	16·0	0·007	0·00093	0·00061
16·0	0·11	0·12	18·5	0·006	0·00091	0·00060
18·0	0·12	0·13	21·0	0·006	0·00089	0·00059
20·0	0·13	0·14	23·0	0·006	0·00088	0·00058

TABLE V.

Jessops Square Self-Hardening Tool Steel.

Dimensions of cross section, 0·64^{cm} × 0·64^{cm}. Wt. per centimeter of length, 3·5 grams.

Length in centimeters.	Approximate magnetic moment per gram at 15° C. of the relaxed steel when magnetized to saturation before the final boiling.	Approximate magnetic moment per gram of the seasoned magnet at 15° C., expressed in c. g. s. units.	Mean loss per degree of the magnetic moment when the magnet is heated from about 15° C. to 100° C, expressed in terms of the moment at the lower temperature.	Temperature coefficient of the seasoned magnet at 15° C.
3·0	8·2	6·0	0·00160	0·00064
4·0	11·5	8·0	0·00099	0·00052
6·0	16·6	12·5	0·00082	0 00045
8·0	23·5	16·6	0·00077	0·00042
10·0	28·0	21·0	0·00074	0·00041
12·0	33·5	25·6	0·00072	0·00040
14·0	38·5	31·0	0·00071	0·00040
16·0	44·6	36·0	0·00070	0·00039
18 0	50·3	41·0	0·00069	0·00039
20·0	55·7	47·0	0·00069	0·00039

The Jefferson Physical Laboratory, Cambridge, Mass.

ART. XLIII.—*A Curious Inversion in the Wave Mechanism of the Electromagnetic Theory of Light;* by C. BARUS.

1. THE account given by the equations of the electromagnetic theory of light as to the motion, is without ambiguity; but when one endeavors to reconstruct such a wave graphically one is apt to fall into a trap such as will make the wave run backwards. To briefly summarize the formulæ relevant to the present paper, I will refer to the mode of derivation in which the conception of a displacement current conditioned by the time variation of electric force is first clearly put. Then the fundamental equation for electric flux in the direction of an axis (Y) in terms of the line integral of magnetic force (α, γ) around that axis is in the usual notation

$$\frac{K}{V}\frac{\delta Y}{\delta t} = \frac{\delta \alpha}{\delta z} - \frac{\delta \gamma}{\delta x} \qquad (1)$$

provided the Hertzian device of measuring electric quantities electrostatically and magnetic quantities electromagnetically is introduced for symmetry. Here V is the normal velocity of light, K the specific inductive capacity of the medium. A clockwise curl of magnetic force around the electric axis is therefore in question.

On the other hand, the fundamental surface integral of magnetic flux in the direction of an axis (z), is expressed in terms of the line integral of electric forces around that axis by

$$-\frac{\mu}{V}\frac{\delta \gamma}{\delta t} = \frac{\delta Y}{\delta X} - \frac{\delta X}{\delta y} \qquad (2)$$

where Hertz's method has again been used and where μ is the magnetic permeability of the medium. The curl of electric force around the magnetic axis is here counter-clockwise. Further equations need not be adduced since the electric forces X and Y in directions x and y and magnetic forces α, γ in directions x and z at the point x, y, z and at the time t, suffice for the present purposes.

From these equations to the differential equations of wave motion, known in form and treated with success even in D'Alembert's time, is not an arduous span. Making it one obtains in the usual way

$$\frac{\delta^2 Y}{\delta t^2} = \frac{V^2}{\mu K}\nabla^2 Y,$$

and

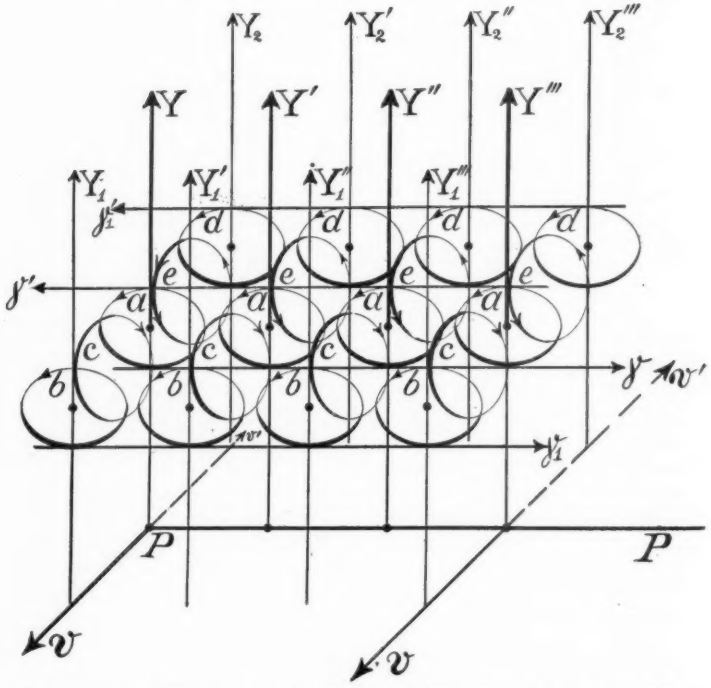
$$\frac{\delta^2 \gamma}{\delta t^2} = \frac{V^2}{\mu K}\nabla^2 \gamma,$$

two equations precisely alike except as to the variables Y and γ. The clockwise and counter-clockwise contrast of (1) and (2) has vanished. $V/\sqrt{\mu K}$ is seen to be the common velocity of the two waves, if waves there be. Applied to plane wave fronts parallel to yz one obtains

$$Y = A \sin 2\pi\left(\frac{t}{T} - \frac{x}{\lambda}\right)$$

$$\gamma = NA \sin 2\pi\left(\frac{t}{T} - \frac{x}{\lambda}\right)$$

where N is the index of refraction, T the period and λ the wave length in the given medium of permeability μ and specific inductive capacity K. The two waves differ merely and naturally in amplitude. They are alike in phase. Nothing is left to recall the opposite signs of (1) and (2). The direction



of common advance is $+x$, when the direction of positive electric force is $+y$ and of magnetic force $+z$, in english or clockwise coördinates. The wave follows the motor rule which,

given in Fleming's lucid way, points the first finger of the *left* hand in the direction of magnetic force, the second finger in the direction of electric current, leaving the thumb in the direction of advance of the wave.

2. Suppose now one endeavors to make a straight-forward step-for-step construction of the electric wave, as is done in the annexed diagram, where full arrows denote magnetic circuits and forces, open arrows the corresponding electric quantities.

Let Y, Y' . . . . in the original plane PP of the wave front, denote the direction of increasing electric force, and therefore of electric polarization and of electric displacement currents. Each current is accompanied by a clockwise whirl, a, a, . . . , of magnetic force encircling it. These forces neutralize each other in the regions between the electric forces, but they have a common direction γ and γ' on either side of the wave front PP. Now let the resulting magnetic forces γ and γ' in their turn be treated individually and each provided with a counter clockwise whirl of electric force, polarization and current, as shown by c, c, . . . around γ and e, e, . . . around γ' respectively. The curls so obtained both tend to neutralize the original electric forces Y, Y', . . . , and to replace them by two new planes of electric force or wave fronts Y_1, Y_1' . . . and Y_2, Y_2' . . . etc. Clearly electric forces above and below the plane γ, γ' would also tend to neutralize each other.

Each of the new electric forces Y_1, Y_1' and Y_2, Y_2', . . . is however again to be provided with a clockwise magnetic whirl b, b . . . and d, d . . . respectively, which together would tend to neutralize γ and γ' and evoke the new magnetic forces γ_1 and γ_1'. Hence by a construction quite recalling Huyghens's principle a new set of electric and magnetic forces Y_1 and γ_1, and Y_2 and γ_1' respectively, have been obtained from the original Y and γ, γ'. The process may be indefinitely repeated, provoking an advance of the wave front in both directions, v and v', from the original wave front PP and at right angle to this plane. In other words, the advance in the figure is to and from the reader.

But unfortunately both waves, if the forces Y and γ are correctly drawn, run in the wrong direction! This may easily be tested by using the left hand as above stated. If the direction of advance v and the electric forces are correct, the magnetic force is in the wrong direction; or finally for correct advance and magnetic force, the electric forces turn out negative. True, since we have two waves moving from each other, the discrepancy could be reconciled by coupling the forces of either wave front with the direction of the other, though such counsel is hardly compatible with sobriety. The very predic-

tion of two waves might be an uncomfortable consideration. In fact only if we accompany the electric current with a counter-clockwise magnetic whirl, and the magnetic flux with a clockwise electric whirl—only by reversing the relations of electric and magnetic field, which everybody is in the habit of associating with electromagnetic phenomena, can we make the wayward wave run right.

3. To arrive at an insight into the conditions here presented one may note that if the Y forces were constant, there would be no magnetic field in the dielectric due to the occurrence of the electric excitation. Since the magnetic forces α, β, γ, are in this case partial differential coefficients of a potential function, there may be a magnetic field due to extraneous causes. This however has nothing to do with the immediate problem. In the diagram Y, Y', . . . would alone occur unaccompanied by magnetic whirls. In the second place if $\delta Y/\delta t$ is constant a magnetic field must be evoked in the dielectric; but this field, apart from the manner of its origin, will during the period of constant $\delta Y/\delta t$ be invariable in intensity and position. It will be a stationary magnetic field, the lines of which are fixed both as to their geometry and their number. As such it is entirely unable to evoke displacement currents. In the above diagram this would mean that, although the forces Y, Y', . . . the whirls a, a, . . . and in consequence the forces γ, γ' exist, the electric whirls e, e . . . and c, c . . . do not exist.

Finally let $\delta^2 Y/\delta t^2$ have a significant value, positive or negative. The values $\delta Y/\delta t$ will then be variable. Displacement currents will therefore be evoked in the dielectric, and the electric whirls c, c . . . and e, e . . . , the resultant electric forces Y_1, Y'_1, . . . and Y_2, Y'_2, . . . , the magnetic whirls b, b . . . and d, d, . . . etc., will in general all have to be entered in the diagram. One may conceive the disturbance to be transferred from PP in both directions indefinitely. It need not however be a harmonic disturbance.

If however the time variation of Y, Y', . . . is simple harmonic, then $\delta^2 Y/\delta t^2$, etc., are essentially negative and negatively increasing of the Y's themselves are essentially positive and increasing; and vice versa. Hence γ is essentially decreasing if Y is essentially increasing in the lapse of time. The magnetic polarization is therefore falling off. The effect of an increasing Y is thus virtually to superpose on any existing magnetic field, new forces γ and γ' which have directions respectively *opposite* to those given in the diagram. These new forces γ and γ' then constitute a *counter-clockwise* whirl of magnetic forces a, a . . . , around the electric forces Y, Y', . . . , thus wholly reversing the directions of the parts a, a . . . , γ and γ' of the diagram.

The same result may be reached somewhat differently: constant $\delta Y/\delta t$ is equivalent to a fixed magnetic polarization in circuit a, the value of which may be either large or small but which is clockwise around Y. Retarded variation of $\delta Y/\delta t$, such for instance as occurs in simple harmonic motion, is thus equivalent to a waning of the clockwise magnetic polarization; or from another point of view, it is equivalent to an increase of counter-clockwise magnetic polarization around Y, hence to a series of counter-clockwise whirls of magnetic force around Y, Y' . . . yielding γ and γ' reversed as resultants.

4. Turning now to the values of γ and γ' which by the present inferences are *opposite* in direction to those given in the diagram, and are increasing in value in this reversed direction at the retarded rate demanded by the simple harmonic equation, it will be expedient to carry forward the argument in the step for step fashion of the preceding paragraph. If γ were constant it would be unaccompanied by an electrical effect, if we except the case that X, Y, Z, may in such a case have a potential due to extraneous causes of no relevant interest. If γ is variable but $\delta\gamma/\delta t$ constant, the result would be an electromotive force curled counter-clockwise around γ. There would be a curled electric polarization of the dielectric but no displacement current around the axis of magnetic force. Finally if $\delta^2\gamma/\delta t^2$ is significant displacement currents must occur and be maintained.

But for the case of an inherent simple harmonic law originating in Y and transferred to γ, the time variation of γ is always retarded from an absolute point of view. Hence the counter-clockwise electric polarization around γ, reversed, is falling off; in other words, clockwise electric polarization around γ reversed is increasing. Virtually therefore a clockwise displacement current is running around γ reversed, i. e. a counter-clockwise current must encircle the γ as drawn in the diagram. Hence both the whirls c, c . . . and e, e . . . , are correctly drawn in the diagram for positive increasing Y, Y' . . . and the new electric excitations (c, e) tend both to weaken Y, and to evoke the new wave front Y_1 and Y_2 as shown.

These forces Y_1 and Y_2 are then to be treated each in its turn in the same way as Y, reproducing the same results indefinitely. Thus the following paradoxical rule relative to the construction of the mechanism of a simple plane electric wave would seem to follow: Provide the original electric flux (Y) with a counter-clockwise magnetic curl (a); provide the resulting magnetic fluxes (γ, γ') each with a clockwise electric curl (c and e); and so forth indefinitely. For such a wave the electric and magnetic forces and the advance of the wave will be in correct directional relations (§ 1, end). The wave would

advance in one direction only if for Y we insert the corresponding gradient $\delta Y/\delta x$ in the direction of advance.

Mathematically stated, if Y is simple harmonic and positive, $\delta^2 Y/\delta t^2$ will be negative and $\delta^4 Y/\delta t^4$ positive again. If therefore clockwise curls are associated with positive fluxes, the magnetic curl around Y conditioned by $\delta^2 Y/\delta t^2$ must be counterclockwise, whereas the electric curl around γ or γ' conditioned by $\delta^4 Y/\delta t^4$ must be clockwise.

5. With the wave disposed of, the question nevertheless remains as to what will happen if the original impulses Y, Y' . . . are not simple harmonic but of a character to make $\delta^2 Y/\delta t^2$ positive. If then $\delta^4 Y/\delta t^4$ is also positive, $\delta^2\gamma/\delta t^2$ is positive and increasing and the above diagram is a correct representation of the case. Energy would be transferred from the original plane PP in both directions v, v', not however as a wave but as simple flux in the direction of the energy paths v, v', until the original stress Y breaks down or follows some other law. It seems to me that the case is not without subtlety and that this nonharmonic rush of electric energy in a direction opposite to the usual energy path cannot be excluded. Its duration would be short since Y, Y' . . . are to remain finite.

Suppose now that such a rush and breakdown occurs irregularly: the irregularity would be accentuated since the energy paths in the rush and the breakdown would in a measure be in opposite directions. Energy so transferred could neither be easily reflected nor refracted and it certainly could not be brought to interference or polarization. In proportion as the rush and breakdown became more and more rythmic or wave-train-like, reflection, etc., would eventually manifest themselves. One is tempted therefore to associate these occurrences with the recent advances in electro-optics, particularly since the deflecting effect of a magnet on the transient electric whirls or their resultants Y, and therefore on the energy path, is not out of the question. During the rush, in other words, the direction of electric current in the whirls or the fluxes Y remains unchanged for relatively long periods, whereas in an ordinary wave these directions are regularly and rapidly reversed in the lapse of time.

Brown University, Providence, R. I.

ART. XLIV.—*On the Determination of Plagioclase Feldspars in Rock Sections;* by GEORGE F. BECKER. (With Plate III.)

IN examining the rocks described in a recent report* pains were taken to determine the species of the lime-soda feldspars by modern methods. The difference of refraction between a mineral and the balsam or between two minerals in contact, according to the method of Prof. F. Becke, is often useful, and Prof. J. E. Wolff was good enough to determine for me the index of refraction (1·5393) of the Canada balsam used in the final mounting of the slides of the U. S. Geological Survey. Much more useful still is the method which Prof. A. Michel-Lévy has developed in two memoirs which should be in the hands of all petrographers.† The method of Mr. Michel-Lévy does not necessitate the use of the Fédoroff table, at least in rocks which show an abundance of well-developed feldspars.

In such rocks it is usually sufficient to deal with the feldspars, which are cut nearly perpendicular to the brachypinacoid (010), g^1 or $\infty P \breve{\infty}$. When a crystal is cut in this zone, of course the albite twin lamellæ extinguish at equal angles on opposite sides of the cross-hair of the microscope. When a crystal is twinned both according to the albite law and the Carlsbad law, this fact can be detected by placing the trace of the twinning plane at an angle of 45° to the principal sections of the nicols. The associated albite twins are then equally illuminated and cease to be apparent. On the other hand, the Carlsbad twins are not then equally illuminated, so that a crystal twinned according to both laws seems to resolve itself into a mere Carlsbad twin. The Carlsbad junction commonly shows signs of interpenetration, and is broken or irregular, while the albite junctions are straight. Supposing such a section in the zone under discussion, one has in general two sets of albite lamellæ, each extinguishing at an equal angle to the cross-hairs, but each pair at a different angle; and furthermore, the orientation of the two pairs of albite lamellæ bear a definite relation to each other, because the difference of orientation is due to Carlsbad twinning. If angles in the zone are counted from the front edge of the prism, and if one pair of albite lamellæ is cut by a plane making an angle ϕ with the front edge, then the other pair of lamellæ is cut at an angle of $180° - \phi$ to the same edge. Mr. Michel-Lévy's beautiful stereographic projections (first fasicle) show how the extinctions in

* This note is an extract from a paper on the Gold fields of Southern Alaska, in the Ann. Rep. U. S. Geol. Surv. 1896–97. part III.

† Étude sur la détermination des feldspaths, 1894. Same, second fascicle, 1896.

such cases will arrange themselves. He has also plotted the extinctions for this particular zone, and shows that when a compound albite-Carlsbad twin is cut in this zone it can in almost all cases at once be referred to its proper species and its proper orientation.

By some mischance errors have crept into this diagram of the extinctions of the feldspars in the zone of symmetry, and I have taken the liberty of replotting it (on Plate III) from the stereographic projections. I have also added plots of the extinctions at 10° from the zone of symmetry in either direction. In a thin section of a rock the chances are infinitely against any feldspar being cut with mathematical precision in the zone of symmetry. Hence the question at once arises how the extinctions will vary in case the plane of symmetry is slightly inclined. These supplementary diagrams give this information at a glance and assure the observer whether or no the variation of the orientation from the position of exact symmetry precludes precise determination.

In a very great number of cases feldspars exhibit traces of zonal structure due to gradual variation in the composition of the successively deposited layers of the crystal. Mr. Michel-Lévy has shown in his second fascicle that if one regards the several plagioclases as mere mixtures of albite and anorthite, instead of as independent species, the position of equal zonal illumination is absolutely characteristic of the orientation of a feldspar in the zone of symmetry. There is only one angle in each quadrant at which equal zonal illumination occurs. This method can be used, for example, in determining when a crystal is cut so nearly perpendicular to the prismatic axis that the extinction of Carlsbad lamellæ should be taken upon opposite sides of the cross-hair. In that case the angle of equal zonal illumination cannot exceed 11°. The angle of equal illumination as a rule is less sharply determinable than, for example, that of equal illumination of albite lamellæ.

In his second fascicle Mr. Michel-Lévy regards all the plagioclases as mere mixtures of albite and anorthite, and defines the special occurrences in percentages. There is, of course, a very great amount of evidence for this position, and, so far as the needs of the working lithologist are concerned, it is probably without sensible error. At the same time it may be remarked that were there no dissipation of energy accompanying the union of the albite and anorthite they would not tend to unite. The liberation of energy corresponding to their actual tendency to union must, one would think, be accompanied by some modification in physical qualities; but this change, so far as known, is negligibly small.

Mr. Michel-Lévy's new attitude toward the feldspars involves

some slight changes in the diagrams. He has given a new diagram for the extinctions in the zone of symmetry, showing the zero angle for the same orientation in all varieties. He does not give a new set of stereographic projections for the several species, and the means are therefore not at hand for plotting the extinctions at 10° from the zone of symmetry. For this reason I have not redrawn the diagram given above of the extinctions. The changes which would be involved appear inconsiderable, and I have found the diagrams for what may be called latitude ±10° too useful to be willing to abandon them. It should be noted that Mr. Michel-Lévy's new fascicle gives stereographic diagrams for microcline.*

While the zone of symmetry is the most useful one, and is usually sufficient where material is abundant, cases also arise in which other parts of the stereographic projections are indispensible. When needful, a skillful use of the stereographic projections will suffice to determine almost any doubly twinned phenocrysts, however cut, and sometimes mere albite twins. With the aid of the Fédoroff or Klein stages any phenocrystic albite twin can be determined, but the use of such a table involves the application of low powers only.

While Mr. Michel-Lévy's method of Carlsbad twins, referred to above, is usually sufficient to determine the species of the feldspars of primary generation in porphyritic rocks, it is not easily applicable to the microlitic feldspar of secondary consolidation. Such microlites are twinned according to both the albite and Carlsbad laws, less frequently than are the phenocrysts; they are also often entirely embedded in groundmass which obscures the extinctions, and relatively high powers must be employed in examining them. Nevertheless, with patience and good eyesight, determinations can often be made. Such determinations have been used as a check upon another method which presents no difficulties, and which will now be described.

In studying the groundmass of lavas from Alaska and California, I have observed many minute, nearly square, sections of plagioclase microlites.† These sometimes show albite twin-

* Taking albite as $NaAlSi_3O_8$, molecular weight 263·36, and anorthite as $CaAl_2Si_2O_8$, molecular weight 279·09, I find the following percentages of anorthite in the several feldspars. Michel-Lévy gives somewhat different values in his second fascicle, page 107.

Feldspar.	Symbol.	Percentage of anorthite.
Albite	Ab	0
Sodium Oligoclase	Ab_4An_1	20·95
Calcium Oligoclase	Ab_3An_1	26·11
Andesine	Ab_2An_2	38·88
Sodium Labradorite	Ab_1An_1	51·45
Calcium Labradorite	Ab_2An_4	58·55
Anorthite	$Ab_{11}An_{200}$	95·06

† The length of a side is usually less than two one-hundredths of a millimeter. Sometimes there are two generations of microlites.

ning parallel to one pair of sides, while in more numerous cases no twinning is visible. They also in some cases exhibit a truncated corner. It appears probable that these microlites are elongated in the direction of the edge between the base and the brachypinacoid, and that they are cut nearly at right angles to this edge, being occasionally truncated by a hemidomal face. This suspicion is confirmed by comparison between the extinctions of such square sections and those of microlites in the same slides which show both albite and Carlsbad twinnings. An elongation in the direction of this edge is also to be expected from Bravais's theory of crystallization; the two faces, base and brachypinacoid, being those of perfect cleavage. Where such microlites present themselves it is easy to see whether they are cut perpendicularly to their axes by following the microlite through the slide; for if the little prism is inclined, the image in focus will shift laterally as the objective moves.

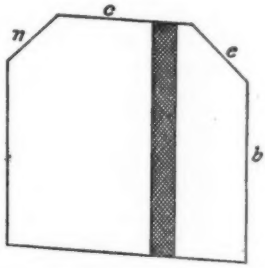
Now it happens that prisms bounded by these faces, and in a vertical position, are very favorably situated for discrimination. This will appear by examining Mr. Michel-Lévy's stereographic projections of the various feldspars at 90° to the pole *p*. In this neighborhood there is a saddle in the extinction surfaces of the feldspars (the central point of the saddle answering to Mr. Michel-Lévy's "most frequent extinction"), and the consequence is that an inclination of even 10° affects the extinction of a square microlite section very little. Furthermore, the difference between the behavior of different feldspars is great, so that a confusion between the different species is almost impossible, as may be seen from the little table below.*

In favorable cases the sign of the extinction can be made useful in the determination of these microlites, which are not really square. In albite the faces *c* (001) and *b* (010) make an angle of 86° 24′, while in anorthite this angle becomes 85° 50′. The divergence from rectangularity is thus sensible, and the proper position of the crystal is then with an acute angle in the upper left-hand quadrant (fig. 1). When the hemi-domal faces appear, *n* (021) truncates the acute angle, making sensibly equal angles of between 46° and 47° with the adjoining faces. The other corresponding hemidome, *e* (021), truncates the obtuse angle and makes angles of from 42° to 43° with the adjoining faces. Andesine and albite can thus be discriminated when orientation is practicable. This discrimination can be confirmed by testing the index of refraction. Andesine has about the

* In this table the percentages of anorthite are given as they appear in Michel-Lévy's work. As is mentioned above, these do not answer precisely to the molecular formulas, but whether the formulas or the percentages need correction I am not certain.

same index of refraction as quartz, and a higher index than balsam, while albite has a lower index than either.

1.



Orthoclase microlites would be exactly square; they would not show polysynthetic twinning, and the index of refraction is much lower than that of oligoclase, which, like orthoclase, extinguishes at 0°.

Extinction of nearly square sections of feldspar microlites cut within 10° of the perpendicular to the edge (001) (010).

Feldspar.	Composition.		Extinction.
Anorthite	Ab_{11}	An_{200} = 96% An	+ 42½° ± 3½°
Calcium Labradorite	Ab_3	An_4 = 60% An	+ 38 ± 3
Sodium Labradorite	Ab_1	An_1 = 47% An	+ 26½ ± 2½
Andesine	Ab_5	An_3 = 34% An	+ 16 ± 2
Calcium Oligoclase	Ab_3	An_1 = 28% An	+ 4 ± 1½
Sodium Oligoclase	Ab_4	An_1 = 18% An	+ 0 ± 1½
Albite	Ab	= 0% An	− 13 ± 2½

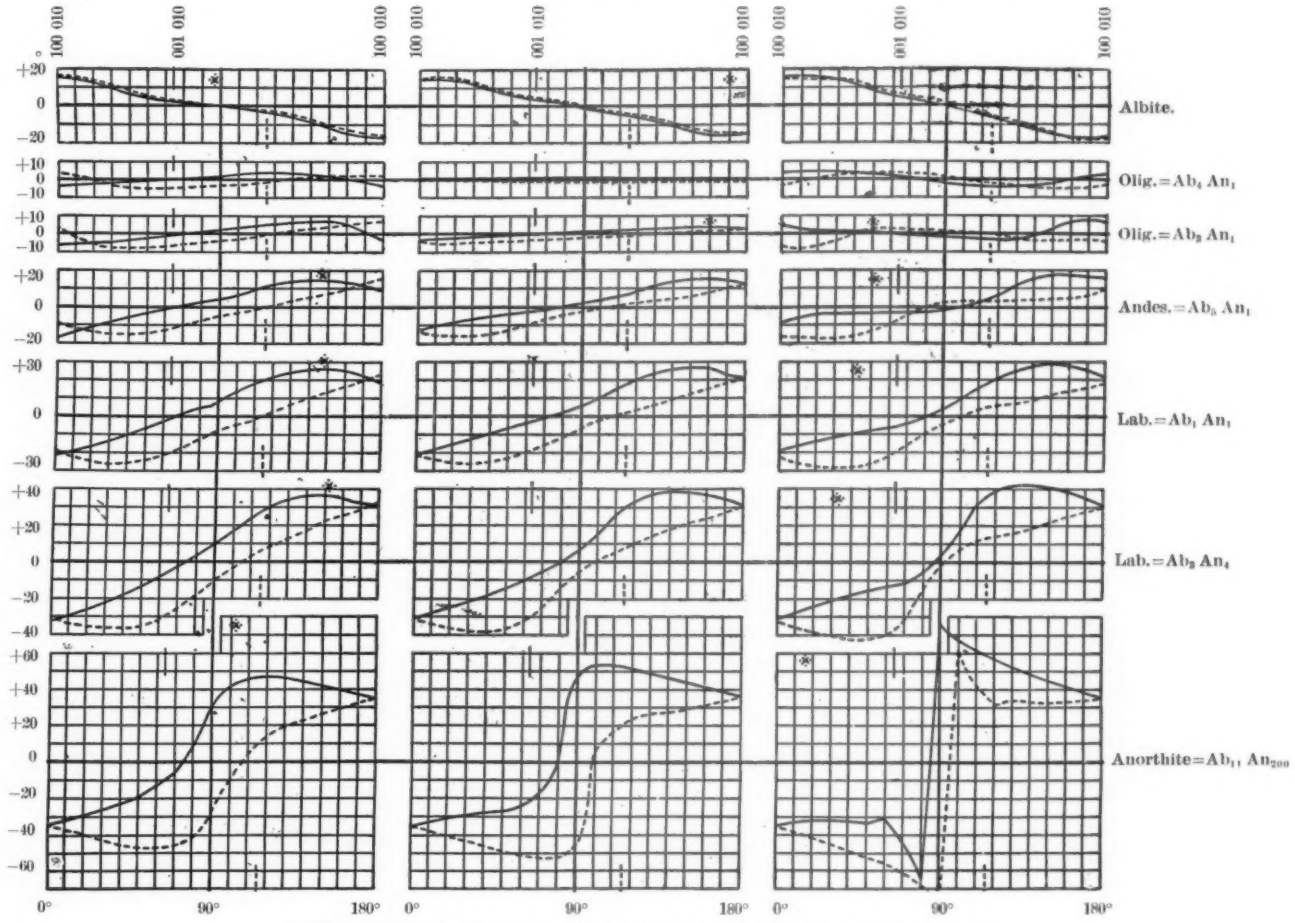
It need not be said that in many rocks the determination of the microlites is quite as important as that of the phenocrysts, their united volume often equaling or exceeding that of the larger crystals. It is also extremely interesting to compare the character of the two generations. It is usually stated or assumed that the microlites are all of one species. The examination of the square sections, of which a dozen or two are often visible in a single slide, leads me to a different conclusion. As a rule the majority do belong to a single species, but it is seldom that two or three out of ten do not belong to a different species; in short, the microlites in the slides I have examined show an irregularity of species of the same order as, and often greater than, that of the phenocrysts. The square sections often show zonal structure, and nearly always the exterior portion is more alkaline than the inner portion; but in a couple of cases this order was found to be reversed. Occasional reversals of this sort are to be found among phenocrysts also.

These facts clearly show that even the residual mother liquor of a consolidating lava is far from homogeneous, even over the area of a square centimeter, and therefore, also, that diffusion in such a liquid must be extremely slow, since diffusion would bring about homogeneity. The bearing of this observation on the theory of "differentiation" of rock magmas is manifest.

The existence of rod-shaped microlites, in connection with the fact that some of them show Carlsbad twinning, throws some light on the origin of twinning. If Carlsbad lamellæ of bacillar shape developed in contiguity but independently, they would form **X**-shaped crystals. These are said to occur, but are not common in my experience.* In the bacillar microlites under discussion one lamella has controlled the development of the rod, and the other lamella has accommodated itself. It is difficult to see how this could happen in mere crystallization, for why should one part resign its tendency to elongation in the direction of the cleavage edge? On the other hand, it is well known, from the investigations of Messrs. Max Bauer, O. Mügge, L. van Werweke, J. W. Judd, and others, that there is much reason to ascribe polysynthetic structure largely to stresses called in play by the cooling process. This theory would fully explain the bacillar microlites as well as some beautiful cases of bent phenocrysts where twinning by various laws stands in manifest relation to flexure. It would also afford an explanation of the fact, of which comparison has convinced me, that twinning is less frequent in the microlites than in the phenocrysts, for the smaller the crystal the less is the chance that external stresses upon it would reach the intensity needful to produce mechanical twinning.

In the same connection it may be noted that stresses such as would lead to the mechanical twinning of plagioclases would also set up a mechanical æolotropy in glass. As a matter of experience, I have found it extremely difficult to detect any absolutely isotropic base in some lavas which I had reason to believe contained a small amount of glass. The faint variation of tints observed with the gypsum plate between crossed nicols in such cases may, perhaps, have been due to strain and not to crystalline symmetry of structure.

* That phenocrysts often take the form of fully developed Carlsbad twins is well known.



EXTINCTION OF TRICLINIC FELDSPARS IN AND NEAR THE ZONE ⊥ 010.

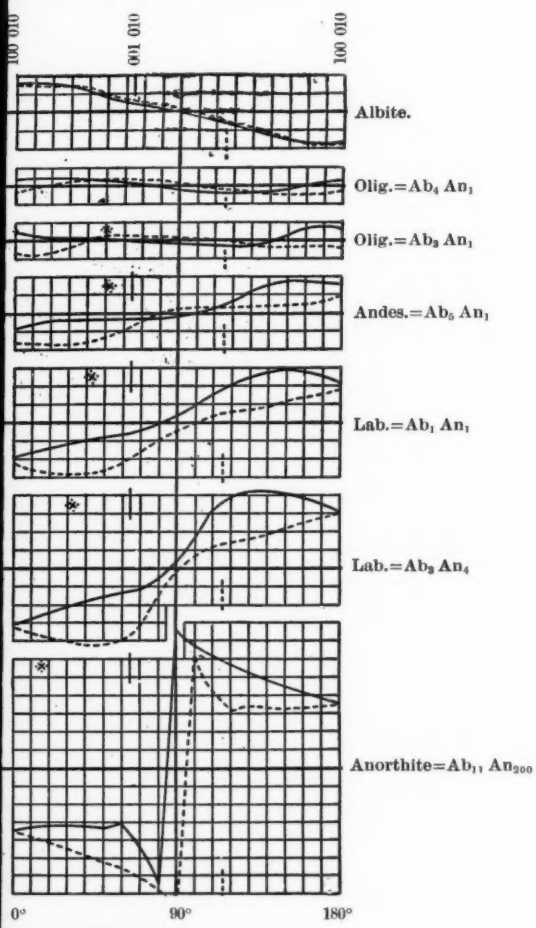
Compiled from M. Michel-Lévy's Étude sur la détermination des Feldspaths, 1894, Plates I–VII.

The extinctions are referred to the trace of the twinning plane and are represented by ordinates. The zero point of the zone answers to the front edge of the prism.

The full line shows the extinction of an untwinned crystal, or of *one* lamella of an albite twin. The dotted line shows the extinction of an associated lamella rotated according to both the albite law and the Carlsbad law.

The stars (*) are placed on ordinates answering to *most frequent extinctions*, the abscissas corresponding nearly to the crystallographic position of these points.

Zone inclined − 10° to A.



NEAR THE ZONE ⊥ 010.

les Feldspaths, 1894, Plates I–VII.

by ordinates. The zero point of the zone answers to the

lbite twin. The dotted line shows the extinction of an

as corresponding nearly to the crystallographic position

ART. XLV.—*Some Lava Flows of the Western Slope of the Sierra Nevada, California;** by F. LESLIE RANSOME.

Introduction.—The field relationships of the rocks described in this paper were studied during the summers of 1895 and 1896, while engaged in geologically mapping portions of the Sonora and Big Trees quadrangles, under the direction of Mr. H. W. Turner. It was found that in addition to the andesitic tuffs and breccias which are so widely and monotonously developed over the broad western slope of the Sierra Nevada, there occurs within the district studied another series of lavas in the form of massive flows, covering much less extensive areas than the clastic andesites. Taken as a whole they form a set of superimposed flows, extending in a southwest direction from some as yet unknown source near the crest of the range, down to the village of Knight's Ferry, near the edge of the Great Valley—a distance of more than 60 miles. Only one of the flows is known to have extended the whole distance, and they have all suffered considerable dissection through the very incisive gashing of the present streams; but in a general way the line of flow may be said to follow the present course of the Stanislaus River. These lava-streams were poured out within the period of eruptive activity during which the andesitic breccias and tuffs were spread for hundreds of square miles over the western flanks of the Sierra. But their eruption was immediately preceded by an interval of sharp erosion, which cut out the channel down which they flowed toward the valley. Subsequently they were again partly covered by fresh deposits of andesitic breccia, especially in the higher portions of the range.

The distinctive chemical feature of these rocks is a rather high percentage of total alkalies, with the potash somewhat in excess of the soda. Chemically they stand between typical andesites and typical trachytes, and belong to a group which it seems necessary to classify under a new name. Without anticipation of a discussion which has its proper place after the rocks themselves have been described, the name *latite* (derived from the Italian province of Latium or Latia, where rocks closely related to those described in the present paper occur extensively) may be considered, for the present, merely as a convenient designation for the group of lavas which form the subject of the present paper, for the purpose of avoiding con-

* Published by permission of the Director of the U. S. Geological Survey; being an abstract of Bulletin No. 89 of the Survey.

fusion with the ordinary clastic andesites abundant in the same field.

The laboratory work embodied in the preparation of the following pages was carried on in the petrographical laboratory of Harvard University, and my thanks are due to Professor Wolff for the excellent facilities there enjoyed. I am also indebted to Mr. Turner, not only for the original permission to undertake the work, but for generously aiding it in many ways.

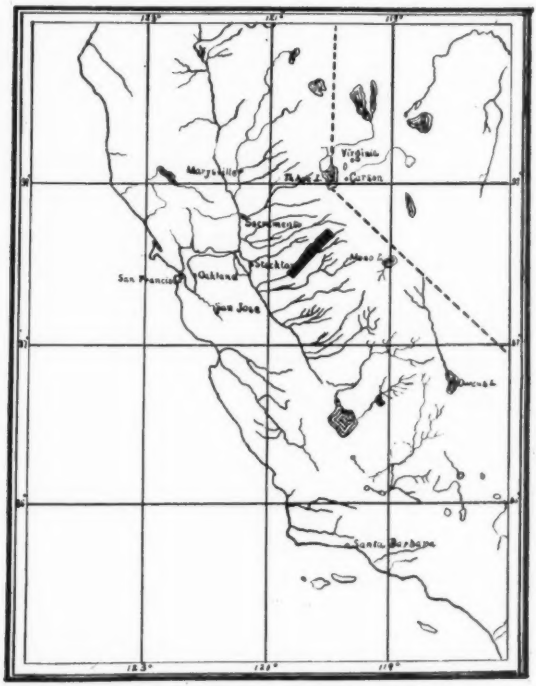


FIG. 1. Index-map showing position of area embraced in Sketch-map, fig. 2.

Physiography of the region.—The accompanying map on page 357 embraces a rectangular strip of country 63 miles in length and 14·5 miles in width, with its longer dimension lying very nearly northeast and southwest. It includes portions of the Oakdale, Sonora, Jackson, Big Trees, Dardanelles, and Pyramid Peak atlas sheets. Considerably more than half the area, however, lies within the Big Trees sheet. The extreme southwestern portion, lying west of longitude 120° 30′ and south of latitude 38°, is taken from the northeast corner of the unfinished Oakdale sheet. The topography is here only partly

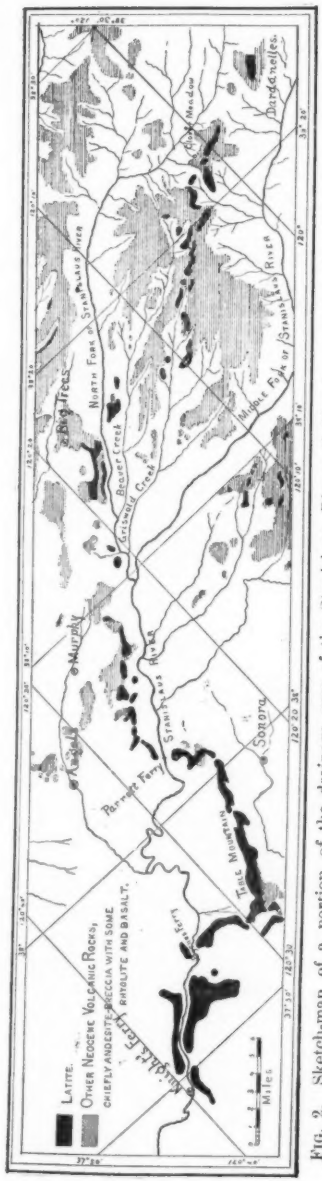


FIG. 2. Sketch-map of a portion of the drainage area of the Stanislaus River, California, showing the distribution of the latites and other Neocene lavas, by F. L. Ransome.

indicated, and the areas of latite are drawn with approximate outlines, subject to future revision. A similar explanation should also be made in regard to the corner of the map lying east of longitude 120°, which is a part of the Dardanelles sheet. The work in this portion of the area was limited to a rapid reconnoissance before the completion of the topographic map.

The elevations, in the region studied, range from a general altitude of about 500 feet, near Knight's Ferry, to 9529 feet on the culminating summit of the group of peaks, in the eastern corner of the area, known as the Dardanelles, corresponding to an average grade of 150 feet per mile. As a whole, this area is practically destitute of alluvial valley-bottoms, and is drained by streams of torrential character. It is traversed from end to end by the young, consequent Stanislaus River, including its two principal branches the North and Middle Forks, and may be regarded as a thoroughly typical transverse strip of the great tilted and dissected peneplain which forms the western slope of the Sierra Nevada. The rocks upon which this rather uneven peneplain has been carved are those of the so-called "Bed-rock Series" of the Gold Belt folios, comprising rocks of Jurassic and pre-Jurassic age, with later intrusive masses, and consisting in

the foot-hill region of closely compressed clay-slates, schists, limestones, quartzites, and various igneous rocks, with a prevailing northwest and southeast strike, and nearly vertical northeast dip, and in the higher portions of the range of gneissoidal and granitic rocks.

Toward the end of the baselevelling process, which, as shown by Diller* and Lindgren† for other portions of the Sierra, lasted at least into the Miocene, the series of volcanic eruptions began which continued through the Pliocene, and ended by covering the old surface far and wide with a blanket of clastic andesitic material in the form of breccias, rolled gravels, and fine tuffs. At the same time began the tilting which has given the peneplain its present slope of about two degrees to the southwest. The old surface revealed to-day by the stripping off of a great part of its andesitic cover, is by no means a perfectly even one. If the sharp V-shaped cañons of post-Tertiary date were all filled up, and the remnants of the Tertiary volcanic cover quite removed, there would still remain a surface of gentle relief surmounted by occasional monadnocks. On the whole though, it would be a topography of greatly subdued relief when contrasted with the possibilities for alpine types of form suggested by the nearly vertical schistose rocks and batholithic plutonic masses out of which it had been carved.

The old peneplain character is not everywhere equally well preserved. In the foot-hill region, embracing roughly the southwestern third of the map, the existence of long belts of highly inclined rocks of varying resistance to erosion, has led to the rapid development of subsequent streams and a general degradation of the surface of the country. The least defacement of the Neocene peneplain is found in the region lying between Murphy and Clover Meadow. Here the homogeneity of the underlying rocks has tended toward the perpetuation of a general consequent character of drainage, the dominant type of topography being that impressed upon the region by the prevalence of long, narrow, and often flat-topped ridges, separated by sharp V-shaped cañons. In the shelter of the latter flourish some of the noblest of forest trees, including the *Sequoia gigantea*, and the beautiful sugar pine, *Pinus lambertiana*. From Clover Meadow northeastward, the Neocene accumulations have been more thoroughly eroded away, leaving a bare hummocky granitic slope, deeply trenched by the gorges of the larger streams, and surmounted by residual

* Topographic revolutions on the Pacific Coast, 14th Ann. Rept. U. S. G. S., pp. 419–421.

† Age of Auriferous Gravels of the Sierra Nevada, Jour. of Geol., vol. iv, pp. 893 and 898.

buttes, or clusters of peaks, such as the Dardanelles, composed of remnants of the former volcanic cover.

The Table Mountain Flow.—The first and longest of the latite flows has been so designated from the fact that it forms the conspicuous topographic feature west of Sonora known as Table Mountain. Starting from Knight's Ferry, this flow can be followed up the Stanislaus River for a distance of about 8 miles to a point near Byrnes Ferry. Along this distance the latite forms broad, flat tables, with black rugged surfaces. The river has cut through the lava, and flows in a picturesque gorge cut deep into the slaty rocks of the Bed-rock series. At the brink of the gorge the edges of the Table Mountain flow form vertical cliffs, usually showing columnar structure. Near Byrnes Ferry the line of the old channel turns eastward for about 4 miles, then again resuming its northeast trend to form the long and imposing rampart of Table Mountain. Owing to the general degradation of the country immediately surrounding it, this portion of the flow, with its strikingly even crest-line and bounding columnar cliffs, is a very prominent feature in the landscape, and has been quite fully described by Trask,* Whitney,† and others, all of whom refer to it as a basaltic flow. Many tunnels have been run beneath the lava of Table Mountain for the purpose of exploiting the auriferous stream-gravels which were buried by its eruption, and subsequently protected by its resistant mass. Near Parrott Ferry the course of the lava-flow again swings northwestward and crosses the present Stanislaus River, here flowing in a deep gorge, 1000 feet below the dissected remnants of the latite that rest upon the brows of the precipitous cañon walls. From Parrott Ferry the formerly continuous lava-stream is now traceable as a series of dissevered patches, lying along the right bank of the main Stanislaus River, and of its North Fork, to a point southeast of Big Trees. Along this portion of its course the Table Mountain flow rests indifferently upon a great variety of rocks, including slates, schists, limestones, quartzites, and gneisses of the Bed-rock series, and gravels, rhyolitic tuff, and andesitic breccia of the Neocene member of the Superjacent series. As a general rule the fragments of the flow hang upon the steep slopes of the cañon rim, forming flat benches which break off abruptly on the river side in columnar cliffs.

Southeast of Big Trees the line of flow crosses the North Fork and can thence be followed as a line of dissevered frag-

* Report on the Geology of Northern and Southern California. Sacramento, 1856. State Senate Doc. 14, p. 20.

† Geol. Survey of California, vol. i, Geology, pp. 243–246. Also Auriferous Gravels of the Sierra Nevada, Mem. Mus. Comp. Zoöl. Harvard Coll., vol. vi, 1880, pp. 131–137.

ments up to the group of peaks known as the Dardanelles. These elevations, consisting of masses of nearly horizontal volcanic material, with a total thickness of from 1200 to 1900 feet, resting upon the worn granitic basement, exhibit an interesting variety of lavas. The westernmost peak of the group was the only one actually visited, and the sequence of the lavas there exposed is as follows: Resting immediately upon the granite on the southwest side of the west Dardanelle is a comparatively thin bed of rhyolitic tuff. This is in turn covered by several flows of olivine basalt aggregating at least 300 feet in thickness. Above the olivine basalt lies the Table Mountain flow, which here attains a thickness of about 500 feet. Its exposed edges break away in imposing columnar cliffs which give the peak its striking outline. At the base of the cliff there is usually a heavy talus of fallen columns, concealing the contact with the underlying olivine basalt. Above the Table Mountain flow, and forming the extreme summit of the west Dardanelle, are portions of the second and third latite flows whose general occurrences are next to be described.

The Biotite-augite-latite.—The rock of the second flow is readily distinguished from that of the flows that followed and preceded it by the presence of abundant megascopic crystals of biotite, and by other characteristic lithological features. It occurs in relatively thin masses, rarely exceeding 50 feet in thickness, usually resting upon the Table Mountain flow, but frequently occurring alone as the only local representative of the latitic series. Like the earlier flow, it followed the old channel already described, but is not known to have extended farther than a point about 4 miles south of Big Trees. In marked distinction from what is known of the earlier and later latite eruptions, the lava of this outburst found its way into other channels besides the main one previously outlined. Thus small patches of the biotite-augite-latite are found north of Big Trees, and south of the Middle Fork of the Stanislaus. On the summit of the west Dardanelle this flow is about 50 feet in thickness, and lies between the Table Mountain flow and the one next to be described.

The Dardanelle Flow.—This, the last product which has been preserved of the activity of the latite vents, has received its designation from the fact that a remnant of the flow forms the extreme summit of the west Dardanelle, and is there typically developed, with a thickness of about 150 feet. Like the first flow, its occurrence is limited, as far as known, to the main Neocene channel, and its remnants have not been detected below the point, about 4 miles south of Big Trees,

already indicated as the lower limit of the biotite-augite-latite.

Microscopic Petrography.—The rock making up the Table Mountain flow is dark in color, and in large masses usually exhibits columnar structure. Near Clover Meadow, however, a portion of the flow has a pronounced spheroidal structure, recalling forms which have been described in the altered Mesozoic basalts of Point Bonita.* In hand-specimens the rock is dark grey, and shows numerous tabular phenocrysts of plagioclase up to 10^{mm} in length, and a few anhedra of augite, lying in a compact aphanitic base. Most specimens show a few small amygdules, and where the bottom of the flow is actually exposed, the large plagioclase phenocrysts are often found scattered through a highly frothy and glassy matrix. Under the microscope it is seen that the phenocrysts, in the order of their abundance, are large well-formed *labradorites*, often spongy with glass inclusions, pale green *augite*, in more or less rounded forms, and *olivine*, usually in small idiomorphic crystals. These lie in a hyalopilitic groundmass consisting of *labradorite* laths, grains of *augite* and a turbid *globulitic glass*. *Magnetite* and *apatite* are present as accessory minerals. The composition of the labradorite phenocrysts, as determined by the method of Michel-Lévy, varies from Ab_1An_1 to Ab_3An_4, and an examination of numbers of the larger laths in the groundmass showed that they possessed approximately the same composition as the accompanying phenocrysts. The rock of this flow has been called an augite-latite.

The biotite-augite-latite of the second flow differs considerably from that just described. It varies from dark to light gray in color, and contains abundant sparkling crystals of biotite, and a few small labradorite phenocrysts, lying in a somewhat porous groundmass. A noticeable feature in most hand-specimens is the presence of irregular and frequently elongated patches of dark glass, and of small pebble-like inclusions, giving the rock at times an almost tuffaceous aspect. Under the microscope, typical facies present a pronounced eutaxitic structure. Phenocrysts of *labradorite*, *biotite*, and *augite* lie in a groundmass in which streaks, patches, and flamboyant tongues, of comparatively clear *glass*, alternate with more turbid areas in which incipient crystallization had already made some progress at the time when the lava solidified. The small inclusions appear in the majority of cases to be more fully crystalline portions of the same magma, which, having solidified, were broken up and involved in the flow by the forward movement of the viscous mass. Other larger inclusions

* University of California, Bull. of Geol., vol. i, pp. 75–80.

are plainly of foreign origin, having been caught up by the lava as it flowed over the underlying andesitic breccias. The accessory minerals are *apatite*, *magnetite*, green *hornblende*, and in one or two cases a few crystals of *hypersthene*.

The Dardanelle flow is composed of augite-latite almost identical in character with that of the Table Mountain flow. It is, however, more compact in texture, and the phenocrysts are smaller. Although characterized by columnar structure, the columns are neither so large nor so regular as those of the earlier flow. Microscopically it differs from the latter in containing somewhat less olivine, and in having a slightly larger proportion of glass. An occasional *zircon* can be noted among the accessory minerals.

In view of the amount of potash shown in all of the chemical analyses of the latite, and the absence of what are commonly regarded as potash-bearing minerals, considerable interest attaches to the residual glass of these rocks. Even in the Dardanelle flow the proportion of glass is not large, and it is difficult to find parts of the section where the glass can be studied without any overlapping of the numerous laths of labradorite. It is moreover rendered turbid by abundant globulites, which were proved to be in large part magnetite, in a very fine state of subdivision. A portion of the powdered groundmass was passed through a number 120 sieve, the dust taken out through a piece of linen, and the remaining powder well washed. After being thoroughly shaken up in Thoulet solution, about half the powder still floated upon dilution to sp. gr. 2·626. Upon subsequent dilution to sp. gr. 2·485, this powder fell, and was readily separable with a weak magnet into two portions, the non-magnetic portion consisting of fragments of more or less impure feldspar, while the darker magnetic powder consisted of globulitic glass with included fragments of labradorite laths. The glass itself has thus a specific gravity much below 2·626. Its index of refraction is lower than that of the balsam (1·540). Grains as pure as possible, picked out under the microscope, afforded abundant crystals of potassium fluosilicate when treated with hydrofluosilicic acid.

Chemical composition of the Sierra Nevada latites.—In the accompanying table on page 363, the chemical analyses of the latites from all three flows are brought together for comparison. In spite of a certain range in the silica percentages, they are clearly closely related members of a series, not far from the andesites in general composition, but slightly higher in silica, and distinctly so in alkalies, the potash, when reckoned in percentages, being always slightly in excess of the soda When, however, molecular proportions are considered, it is more accurate to say that potash and soda are present in nearly equal amounts. As would be expected from the study

of the thin-sections, the rock of the Table Mountain flow is more basic than the biotite-augite-latite, while that of the Dardanelle flow occupies an intermediate position. Titanic acid is present in all of the analyses, and usually in notable

TABLE OF CHEMICAL ANALYSES OF SIERRA NEVADA LATITES.

	I.	II.	III.	IV.	V.	VI.	VII.
SiO_2	56·19	59·88	56·78	59·43	61·09	62·33	65·81
	·936	·998	·946	·990	1·018	1·039	1·096
TiO_2	·69		1·15	1·38		1·05	·54
Al_2O_3	16.76		16·86	16·68		17·35	15·11
	·162		·163	·161		·168	·146
Fe_2O_3	3·05		3·56	2·54		2·98	1·85
	·019		·022	·015		·018	·011
FeO	4·18		2 93	3 48		1·63	1·40
	·058		·040	·048		·022	·019
MnO	·10			tr.		·08	
MgO	3·79		3·41	1·84		1·05	·37
	·094		·085	·046		·026	·009
CaO	6.53	5·08	6·57	4·09	4·94	3·23	1·98
	·116	·090	·117	·073	·088	·057	·035
BaO	·19			·14		·24	·10
SrO	tr.			tr.		·05	
Na_2O	2·53	3·90	3·19	3·72	3·69	4·21	2·59
	·040	·062	·051	·059	·059	·067	·041
K_2O	4·46	5·06	3·48	5.04	5 27	4·46	5 24
	·047	·053	·036	·053	·055	·047	·055
Li_2O	tr.			none.		tr.	
H_2O above 110°	·66		1·21	·72		·75	
H_2O below 110°	·34		·15	·27		·44	
P_2O_5	·55		·42	·58		·29	·23
			CO_2 ·18	ZrO_2 ·08		FeS_2 ·08	
				Cl ·05		C ·11	
	100·02		99·89	100·04		100·33	
Sp. gr.			2·67	2·61		2·49	2·38

I. Augite latite. Table Mountain Flow. Tuolumne Table Mt., W. of Sonora. (36 S. N.) W. F. Hillebrand, analyst. H. W. Turner, 14th Ann. Rept. U. S. Geol. Survey, p. 491.

II. Augite-latite. Table Mountain Flow. 3 mi. E. of Big Trees. (86 S. N.) P. Fireman, analyst. H. W. Turner, 17th Ann. Rept. U. S. Geol. Survey, p. 727.

III. Augite-latite. Table Mountain Flow. Near Clover Meadow. (1422 S. N.) G. Steiger, analyst.

IV. Augite-latite. Dardanelle Flow. 4 mi. S. W. of Clover Meadow. (1419 S. N.) H. N. Stokes, analyst.

V. Biotite-augite-latite. 3 mi. E. of Big Trees. (85 S. N.) P. Fireman, analyst. H. W. Turner, 17th Ann. Rept. U. S. Geol. Survey, p. 727.

VI. Biotite-augite-latite. 4 mi. S. W. of Clover Meadow. (1420 S. N.) W. F. Hillebrand, analyst. H. W. Turner, 17th Ann. Rept. U. S. Geol. Survey, p. 727.

VII. Biotite-augite-latite (?). Near mouth of Griswold Creek. (1866 S. N.) G. Steiger, analyst.

amount, indicating that the magnetite is probably titaniferous. Analysis number VII, in addition to being unusually high in silica, is low in lime and magnesia, thus approaching more nearly the chemical character of a trachyte. This is a glassy,

pitchstone-like facies, which on petrographical grounds was correlated with the biotite-augite-latite of the second flow. There are certain relations which suggest, however, that it may really have preceded the Table Mountain flow instead of following it. The chemical analysis lends additional color to this suggestion, and it is possible that in the two small masses, which alone are known of this rock, there may survive the remnants of an earlier flow than any of the three typical latite considered in this paper.

The most noticeable feature of the analyses as a whole, taken in connection with the mineralogical composition of the rocks, is the amount of potash present. By far the greater number of the thin-sections (excepting of course the biotitic facies, which however are no richer in potash than the others) contain no recognizable potash-bearing mineral. Several of the analyses contain as much as 5 per cent of potash, which, if it were present in the form of orthoclase, would make up nearly 30 per cent of the rock. This amount is entirely too large to be accounted for on the supposition that it is present in the form of orthoclase microlites which have escaped detection among the plagioclases of the groundmass, and it is fairly certain that nearly all this potash, in those facies which do not contain biotite, is present in the residual glass of the groundmass.

It is frequently observed* that in rocks of intermediate composition, like the latites, orthoclase forms a thin envelope around the basic plagioclases, while in the plutonic monzonites the orthoclase was the last to crystallize, forming a mesostasis for the earlier minerals. In the Sierra Nevada latites the conditions under which orthoclase (or some other potash alumina silicate) could separate out were never reached. This would indicate that the method, not infrequently resorted to, of assuming the presence of orthoclase in the groundmass of an effusive rock from the chemical composition of the latter, requires caution in its use.

Classification of the Sierra Nevada latites.—With the advance made in methods of petrographical research during recent years, there has come inevitably greater difficulty in the proper classification of the rocks themselves. The increased refinement in chemical analyses, and their more critical interpretation, together with the strides made in the optical investigation of the feldspars by Becke, Federow, Michel-Lévy, and others, is leading to the gradual splitting up of some of the older, more comprehensive groups. A notable example of this tendency was Brögger's differentiation of the monzonite family from the syenites, while a similar process has long been reducing the once large family of the trachytes to a size more commensu-

* See Washington, Jour. Geol., vol. iv, p. 551, for several references.

rate with the minor importance of their plutonic equivalents. Together with the establishment of new families there has come into the literature an enormous number of new rock names. In many cases these names are local, being based on mineralogical combinations and distinctions that may not be repeated in another region, or given the same values by another observer. The common custom of providing such facies with a name, derived from the locality in which they occur, is a useful one, but the local, and to a certain extent provisional, nature of such names should be borne in mind, and they should not be allowed to bury under their accumulating mass broader and more rational schemes of classification.

COMPARATIVE TABLE OF CHEMICAL ANALYSES.

	I.	II.	III *	IV.	V.*	VI.	VII.	VIII.	IX *	X.*	XI.	XII.
SiO_2	55·44	55·69	56·19	56·76	56·78	57·97	58·67	59·41	59·43	59·88	60·03	60·88
TiO_2	·16	tr.	·69		1·15			·01	1·38			
Al_2O_3	18·60	19·08	16·76	16·79	16·86	17·65	15·07	17·92	16·68		17·05	16·19
Fe_2O_3	2·09	4·07	3·05	2·07	3·56	·63		1·71	2·54		1·83	5·37
FeO	4·48	3·26	4·18	6·95	2·93	7·50	8·35	2·40	3·48		4·15	1·58
MnO		tr.	·10			·09			tr.		·09	
MgO	4·75	3·41	3·79	1·63	3·41	1 71	2·97	2 99	1·84		1·12	2·96
CaO	6·75	6·87	6·53	6 01	6·57	5·53	8·07	4·65	4·09	5·09	6·58	5·88
BaO			·19						·14			
SrO			tr.						tr.			
Na_2O	1·79	2·89	2·53	2·43	3·19	1·50	3·36	2·63	3·72	3·90	2 31	3·11
K_2O	6·63	4·41	4·46	4·67	3·48	5·31	3·50	5 60	5·04	5·06	5·12	3·95
Li_2O			tr.									
P_2O_5	tr.		·55	·47	·42	·42		·87	·58		·42	
H_2O above 110°			·66		1·21				·72			
H_2O below 110°			·34		·15				·27			
Ig. or total H_2O	·25	·17		2·44		1·82	·82	1·30			1·42	·98
					CO_2 ·18				ZrO_2 ·08			
									Cl ·05			
Totals	100 75	99·85	100·02	100·22	99·89	100·13	100·81	99·49	100·04		100·12	100·70

	XIII.*	XIV.	XV.	XVI.*	XVII.	XVIII.	XIX.*	XX.	XXI.	XXII.	XXIII.
SiO_2	61·09	61·44	61·93	62·33	63·17	63·49	65·81	58·47	60·97	57·29	60·89
TiO_2				1·05		tr.	·54	·51		·72	·49
Al_2O_3		17·08	18·47	17·35	17·15	18·40	15 11	18·80	20·92	18·45	17·14
Fe_2O_3		3·67	1·93	2·98	2·84	2·44	1·85	3·34	3·81	4·38	3·32
FeO		2·42	2·23	1·63	1·31	1·09	1·40	2·64		1·20	·95
MnO				·08		·16		·13		tr.	·09
MgO		1·14	2·66	1·05	2·17	·66	·37	2·69	·29	2·08	1·16
CaO	4·94	6·21	4·31	3·23	4·17	2·30	1·98	6·60	·14	3 57	3·58
BaO				·24			·10	·09			
SrO				·44				·05			
Na_2O	3·69	4 06	2·92	4·21	3·08	5·70	2·59	3·58	5·03	4·43	4·54
K_2O	5 27	3·86	3·92	4·46	4·19	4·62	5·24	2·01	8·88	5·43	5·71
Li_2O				tr.				tr.			
P_2O_5				·29		tr.	·23	·22		·46	·27
H_2O above 110°				·75				·92			
H_2O below 110°				·44				·14			
Ig. or total H_2O		2·04	2·28		2·51	1·04			·83	2·18	1·61
				FeS_2·08		CO_2 tr.				NiO ·12	NiO ·19
				C ·11							
Total		101·92	100·65	100·33	100·59	99·90		100·19	100·42	100·31	99·94

* Sierra Nevada latites.

	XXIV.	XXV.	XXVI.	XXVII.	XXVIII.	XXIX.	XXX.	XXXI.	XXXII.	XXXIII.
SiO_2	52·16	52·53	52·81	54·20	54·42	57·66	58·05	58·98	61·72	61·73
TiO_2			·71	·40	·80					
Al_2O_3	22·11	19 48	15·66	15·73	14·28	17·23	17·71	17·34	13·57	17·45
Fe_2O_3	8 58	11·07	3·06	3·67	3·32	7·28	8 29	3·44	7·60	5 94
FeO			4·76	5·40	4·13					
MnO			tr.	·70	·10				·33	
MgO	2·64	1·53	4·99	3·40	6·12	2 20	2·07	1·63	3·33	2·29
CaO	8·61	6·61	7·57	8 50	7·72	5·32	5·81	8·64	5·88	4·52
BaO			·24		·32					
SrO			·09		·13					
Na_2O	3·35	2·71	3·60	3·07	3·44	3·41	2·98	3·41	3·12	3·12
K_2O	2·00	3·17	4·84	4·42	4·22	4·61	3·24	5·34	3·37	3·88
Li_2O			tr.		tr.					
P_2O_5			·75	·50	·59					
H_2O above 110°			·93		·38					
H_2O below 110°			·16		·22					
Ig. or total H_2O	·80	2·34		·50		·70	1·34	1·06	·95	1·16
			Cl ·07			CO_2 76				
			Fl tr.							
			SO_3 tr.							
Total	100·25	99 44	100·24	100.50	100 19	99·17	99·49	99·85	99 43	100·09
			·02							
			100·22							

I. Ciminite, Fontana Fiescoli, Viterbo, Italy. Jour. Geol., vol. iv, p. 849. H. H. Washington, analyst.

II. Biotite-vulsinite, Monte Santa Croce, Rocca Monfino Region, Italy. Jour. Geol., vol. v, p. 252. H S. Washington, analyst.

III. Augite-latite, Table Mountain, Tuolumne Co., Cal. (36 S. N.)

IV. Olivine-bearing andesitic trachyte, Sassara, Italy. Klein, Neues Jahrbuch für Min., etc., B.B. vi, p 8. Ricciardi, analyst.

V. Augite-latite, Table Mountain flow, 1½ mi. E. of Clover Meadow. (1422 S. N.)

VI. Trachyte (Klein) or Vulsinite (Washington), Bolsena, Italy. Klein, loc. cit. Ricciardi, analyst.

VII. Ciminite, Monte Cimino, Italy. Jour. Geol., vol. iv, p. 849. Vom Rath, analyst.

VIII. Andesite, Cabezo Felipe, Cabo de Gata Spain. Zeitschr. Deutsch. geol. Gesell., vol. xliii, 1891, p. 719. Osann, analyst.

IX. Augite-latite, 4 mi. S.W. of Clover Meadow. (1419 S. N.)

X. Augite-latite, 3 mi. S.E. of Big Trees. (86 S. N.)

XI. Trachyte (Klein) or Vulsinite (Washington), San Magno, Italy. Klein, Neues Jahrbuch für Min., etc., B.B. vi, p. 10. Ricciardi, analyst.

XII. Augite-andesite, Mt. Pagos, Asia Minor. This Journal, IV, vol. iii, p. 43. Washington, analyst.

XIII. Biotite-augite-latite, 3 mi. S.E. of Big Trees. (85 S. N.)

XIV. Trachyte, Gleichenberg. Tschermak's Mineral. Mittheil., 1877, p. 277. Smita, analyst.

XV. Augite-andesite, Kara Tash, Asia Minor. This Journal, IV, vol. iii, p. 45. Washington, analyst.

XVI. Biotite-augite-latite, 4 mi. S.W. of Clover Meadow. (1420 S. N.)

XVII. Biotite-dacite, Pergamon, Asia Minor. This Journal, IV, vol. iii, p. 49. Washington, analyst.

XVIII. Sanidine-bearing andesite, Rosita Hills, Col. Cross, Proc. Colo. Sci. Soc., 1887, p. 250. Eakins, analyst.

XIX. Biotite-augite-latite (?), near mouth of Griswold Creek. (1866 S. N.)

XX. Hornblende-pyroxene andesite, Downieville Quadrangle, Cal. Turner, 17th Ann. Rept. U. S. Geol. Survey, p. 731. Hillebrand, analyst.
XXI. Trachyte (Domite), Puy de Dôme, France. Zirkel, Lehrbuch der Petrographie, ii, p. 378. Lewinstein, analyst.
XXII. Quartz-banakite, dyke near head of Stinkingwater River, Yellowstone Park region. Iddings, Jour. Geol., vol. iii, p. 947. Melville, analyst.
XXIII. Quartz-banakite, dyke, locality and reference as above.
XXIV. Monzonite, Predazzo. Brögger, Die Eruptionsfolge der triadischen Eruptiogesteine bei Predazzo in Südtyrol, Kristiania, 1895, p. 25.
XXV. Monzonite, Sasinathal, Predazzo. Brögger, loc. cit.
XXVI. Monzonite, Beaver Creek, Mont. Weed and Pirsson, this Journal, IV, vol. i. p. 357. Stokes, analyst.
XXVII. Monzonite, Monzoni, South Tyrol. Brögger, op. cit., p. 24. Schmelck, analyst.
XXVIII. Monzonite, Yogo Peak, Mont. Weed and Pirsson, loc. cit. Hillebrand, analyst.
XXIX. Monzonite, Mulatto, Predazzo. Brögger, op. cit., p. 25.
XXX. Monzonite, Malgola, Predazzo. Brögger, loc. cit.
XXXI. Monzonite, Predazzo. Brögger, loc. cit.
XXXII. Monzonite, Blansko, Mälvren. Brögger, op. cit., p. 50.
XXXIII. Monzonite, Hodritsch, Hungary. Brögger, loc. cit.

On the other hand, it is no part of pure petrographical science to aim directly at ease and simplicity in classification, however desirable that end may appear to the general geologist. Petrography in its present stage is occupied rightly with critical distinctions, and it is only by the recognition of such slight points of difference that they can ever be transcended, and assigned their true value in a really rational scheme of rock classification.

Recognizing the fact that igneous rocks are chemically mixtures, of practically infinite variability within certain limits, the refining tendency of modern methods tends more and more toward precision of definition, and a consequent subdivision of the older groups. This gain in precision by no means makes the classification of a given rock an easier matter, for it is evident that the greater the number of families, the more numerous will be the intermediate or transition rocks, since sharp lines of demarcation apparently nowhere prevail between closely related types. It is a question of course how far, for purposes of practical description, such subdivision of large groups should go, but it is a question that may be very well answered by the facts of geological occurrence. If a magma of a certain intermediate type with reference to two or more well established families is found to possess geological unity, and particularly if it is found to be represented by both plutonic and effusive forms, there can be little doubt of the advisability of giving it a distinctive name. Brögger's monzonite magma is an example of such a case, and he has shown very conclusively that the plutonic monzonites, being orthoclase-plagioclase rocks, should be separated from the orthoclase

rocks, or granites and syenites, on the one hand, and the plagioclase rocks, or diorites and gabbros, on the other, the mineralogical distinction being the visible sign of difference in chemical composition. In his tabular classification* he has indicated the effusive equivalent of monzonite as *trachyte-andesite*, and it is here that the latites of the present paper belong, as will now be more fully shown.

It is plain from the descriptions of the latites in the preceding pages, that in spite of their superficial basaltic character, they are in no sense basalts, being far too high in silica and alkalies, and too low in magnesia and lime, and differing from the latter rock in microscopic structure, and in the proportion of ferromagnesian constituents to the feldspars. Their specific gravity, too, is lower than that of basalts of equally compact texture.

Their relation to the andesites is much closer, and were it advisable to crowd them into one of the well-established older groups they would be placed with little hesitation in this family. Leaving out of consideration the glassy base, the latites described in the present paper possess practically the mineralogical composition of andesites. But they differ from normal andesites in chemical composition, being generally slightly lower in lime and magnesia and always higher in alkalies. In the andesites the total alkalies are as a rule less than six per cent, with soda in excess of potash. In the latites the total alkalies range from six to ten per cent, with the potash, reckoned in percentages, equal to or slightly in excess of the soda.

Rocks of this type can hardly be classed as trachytes if the latter name is to retain any precision of meaning. Not only are they decidedly untrachytic in color and texture, but differ widely mineralogically from typical trachytes. Sanidine, instead of being the dominant feldspar, is entirely absent and the conspicuous phenocrysts are labradorite. Mr. Turner† has provisionally classed some of the latites with the trachytes on the basis of their chemical composition. The analysis upon which the comparison is based was quoted from Zirkel's Petrographie‡ and as Mr. Turner remarks "contains more lime and less silica than most of the analyses given by Zirkel." The analyses in question is one by Ricciardi§ of the so-called trachyte of Bolsena, and is quoted in column V of

* Die Eruptivgesteine des Kristianiagebietes; II Die Eruptionsfolge der triadischen Eruptivgesteine bei Predazzo in Sudtyrol, Kristiania, 1895, p. 60.

† Further Contributions to the Geology of the Sierra Nevada, 17th Annual Rept. U. S. Geol. Survey, p. 729.

‡ Vol. ii, p. 378 (1893).

§ Klein, Petrographische Untersuchung einer Suite von Gesteinen aus der Umgebung des Bolsener Sees; Neues Jahrb. für Min., etc., B.B. vi, 1889, p. 8.

the table of chemical analyses. Concerning this rock Washington writes: "Vom Rath first called attention to the abnormal chemical character of the 'trachyte' of Bolsena, though he speaks of it as containing no plagioclase, probably owing to the rarity of the multiple twinning. As will be seen from Klein's descriptions and my own, and from the analyses, the peculiar 'trachytes' of the region are remarkable: mineralogically for their richness in plagioclase and the frequent occurrence of olivine as an essential constituent, and chemically for their low silica and high lime and magnesia. Therefore they are not trachytes proper, but correspond to the trachy-dolerites of Abich and Hartung, and to some of the andesitic-trachytes of Rosenbusch, and we shall see that they may be regarded as effusive representatives of Brögger's abyssal monzonites. These olivine free effusive rocks will be called by the name of *Vulsinite* from the Etruscan tribe Vulsinii, formerly inhabiting this region."* There is thus fresh confirmation of the result already stated, that the latites of the present paper belong neither with the normal trachytes nor yet with the normal andesites, but occupy a position chemically about midway between the two.

Effusive rocks with a chemical composition corresponding to this intermediate taxonomic position appear to be not uncommon, and on pages 365 and 366, the chemical analyses of a number of such rocks have been placed together in tabular form. Numbers I to XIX inclusive are analyses of latites, which in the table are given the names assigned them by the authors quoted. Numbers XX and XXI, in the middle division of the table, are a typical andesite and typical trachyte respectively, being inserted to show the intermediate character of the latites. The latter as a whole form a fairly uniform chemical series.

But when attention is directed to the names and descriptions of the various effusive rocks embraced in the table, they are found to be remarkable more for variety than uniformity. Thus, besides the latites described in the present paper, there occur such names as *ciminite*, *biotite-vulsinite*, *olivine-bearing andesitic trachyte*, *vulsinite*, *andesite*, *augite-andesite*, *trachyte*, *biotite-dacite*, and *sanidine-bearing andesite*. At first glance such an abundance of names for effusive rocks of a single chemical type seems to indicate little else than a state of hopeless confusion in rock nomenclature. But while a certain amount of confusion does undoubtedly exist, the multiplicity of names has its chief explanation suggested by two other facts—partly, as pointed out by Iddings,† that rock-series as

* Italian Petrological Sketches, Journal of Geology, vol. iv, p. 547.
† Journal of Geology, vol. iii, pp. 955–956.

they occur in nature may traverse existing schemes of classification at practically any angle, but mainly, in this case, that the name of a rock is generally determined more by its mineralogical than by its chemical composition.

In the case of most igneous rocks, and of nearly all plutonic rocks, the principal mineralogical constituents can be deduced with a fair degree of certainty from an accurate bulk-analysis, and *vice versa*, the chemical constitution can be predicted from a microscopical investigation of a thin-section with sufficient accuracy to leave little doubt of the general position of the rock in an ordinary scheme of classification. But with the effusive latites this appears to be true only in a slight degree. In effusive rock of intermediate chemical composition the circumstances which determine the crystallization of the different possible mineralogical combinations, appear to depend upon a very delicate adjustment of physical and chemical conditions. This is already noticeable in the andesites, where a given magma cooling under certain conditions may give rise to a hornblende or biotite andesite, and under other conditions, by the magmatic resorption of these two minerals, may solidify as a pyroxene andesite. The latites, being intermediate rocks *par excellence*, and containing more or less unindividualized glass in reserve, exhibit this apparent capriciousness of crystallization to an unusual degree.

Thus, the vulsinites of Washington "are characterized mineralogically by the presence of alkali feldspar with a large amount of basic plagioclase (labradorite to anorthite), together with augite and diopside. Hornblende and biotite are not abundant in the type specimens, though they may be present in large amounts in other varieties. . . . . Olivine is wanting, or if present is so in only accessory amounts."*

The biotite-vulsinite from Monte Santa Croce (column II) is particularly interesting with reference to the point under discussion, and the dilemma in which one is placed in attempting to adhere to a purely mineralogical classification of these rocks is well expressed in Washington's own words. He says: "We have then a rock which is chemically a ciminite and mineralogically a biotite-vulsinite.

"In regard to the name by which they should be called there may be some doubt. From a mineralogical standpoint they are obviously not ciminite, nor chemically can they strictly be called vulsinite. Since, however, in the schemes of classification in general use at the present time, the mineralogical composition takes precedence over the chemical, and bearing in mind the unadvisability of adding new names to the already overburdened nomenclature, I shall designate these rocks as biotite-vulsinite."†

* Journal of Geology, vol. iv, p. 553.
† Journal of Geology, vol. v, pp. 250–251.

The ciminites are "characterized mineralogically by the presence of orthoclase, with basic plagioclase, augite or diopside, and olivine."*

The andesite from Carbezo Felipe contains phenocrysts of feldspar and biotite. Sanidine occurs in crystals over a centimeter in length, but the main bulk of the feldspar is labradorite and andesine. Both monoclinic and orthorhombic pyroxene are present, and the rock is rich in zircon and apatite.

Concerning the classificatory position of this rock Osann writes: "Das Verhältniss der Alkalien lässt das Gestein als der Gruppe der andesitischen Trachyte nahestehend erkennen, worauf auch die vereinzelten grösseren Sanidin-Einsprenglinge hinweisen; der hohe Kalk- und Kaligehalt gegenüber den geringen Mengen an Natron erklären sich aus der Beobachtung, das neben dem Sanidin ein basischer Plagioklas (Labrador) als Einsprengling vorhanden ist. Vergleicht man die Analyse mit derjenigen anderen andesitischer, theilwise Olivin führender Trachyte (Mte. Amiata, Arsostrom, Mte. Alfina) so fällt ihr hoher MgO-Gehalt auf (im Arsogestein trotz des Olivingehaltes nur 1·77 p. ct.), derselbe findet nur in der gleichzeitigen reichlichen Anwesenheit von Biotit und rhombischem Pyroxen seine Erklärung."†

The augite-andesite from Mt. Pagos is "composed of plagioclase, diopside, and biotite, with accessory magnetite, apatite, and zircon, lying in a glass base."‡ The plagioclases are labradorite, but there are possibly a few orthoclase microlites in the groundmass.

The Gleichenberg trachyte contains, according to Hussak, large sanidine phenocrysts, fewer and smaller ones of oligoclase, biotite, and dark augite, in a globulitic base.§

The augite-andesite from Kara Tash has numerous phenocrysts of labradorite (a little more basic than Ab_1An_1), pale green diopside, some biotite, and grains of magnetite, in an abundant trichitic, glassy base.‖

The biotite-dacite from Pergamon¶ contains phenocrysts of labradorite, with fewer sanidines, biotite, and olive-green hornblende. The rock is called a dacite on the basis of its chemical composition, although containing no free quartz, thus again illustrating the difficulties attendant upon a consistent mineralogical classification of these intermediate rocks.

* Journal of Geology, vol. iv, p. 838.

† Beitrage zur Kenntniss der Eruptivgesteine des Cabo de Gata, II; Zeitschr. d.d. geol. Gesell., vol. xliii (1891), p. 720.

‡ Washington, On Igneous Rocks from Smyrna and Pergamon; this Journal, vol. cliii (1897) p. 43.

§ Zirkel, Lehrbuch der Petrographie, ii, p. 383.

‖ On Igneous Rocks from Smyrna and Pergamon; this Journal, vol. cliii, p. 44.

¶ Ibid., p. 48.

The sanidine-bearing andesite of the Rosita Hills is described by Cross* as containing plagioclase, orthoclase, quartz, biotite, augite, and accessory minerals. The plagioclase is referred to oligoclase. This rock is said to have its chief development as dykes, although occurring also in effusive masses.

The foregoing citations are sufficient to show how great mineralogical variety may be presented by the effusive rocks having the peculiar intermediate chemical composition of the latites. It is possible, and perhaps desirable, to assign the more conspicuous and well-marked of these mineralogical combinations separate names, but the number of the latter is apt to be large, and they are of a distinctly lower grade of importance than those rock names that express not only a certain mineral constitution but a corresponding and characteristic chemical composition as well.

It accordingly seems advisable to attempt to bring into use some more general name to embrace all the effusive rocks standing chemically about midway between the typical trachytes and the typical andesites,—a name that can be used as the general effusive equivalent of the increasingly important group of the plutonic monzonites. I should gladly have avoided the necessity of introducing a new name into a rapidly growing nomenclature, the more so, as Washington, by his admirable petrographical studies in the Italian volcanic regions, has added so greatly to an accurate knowledge of intermediate rock types which must be necessarily embraced by such a new term. But the Sierra Nevada lavas cannot be classed with the typical toscanites, vulsinites, or ciminites, as defined by Washington, although, like the vulsinites and some of the ciminites, they are to be regarded as the effusive equivalents of the monzonites. Thus there is an imperative demand for some more comprehensive name to cover the mineralogically diverse forms which monzonitic magmas, cooling under effusive conditions, may assume. For this reason, and in recognition of the importance and interest of the Italian types described by Washington, the name *latite*, derived from the Italian province of Latium, is proposed as a broader term, comparable in its scope with *monzonite*, to designate the effusive forms of the monzonite magma. It is to be noted, that the particular facies of latite represented by the Sierra Nevada lavas might also be given varietal names of the same order of importance as vulsinite or ciminite; but this has not been done in the present instance.

Abich and Hartung have used *trachy-dolerite* for rocks which in part belong with the latites; Fouqué and Michel Lévy, *trachy-andesites;* Zirkel and Rosenbusch, *andesitic-trachyte;*

* Proc. Colorado Scientific Soc., 1887, p. 248.

and Brögger *trachyte-andesite.* But all these compounds are open to objection when a name is required for an important group, standing midway between the trachytes and andesites. Such a name should above all consist of a single word, and should be free from the undesirable connotations adherent to compounds which have been variously employed.

Referring again to the table of chemical analyses, it will be seen that in columns XXII and XXIII are placed the analyses of two quartz-banakites, chosen as being the nearest known dike equivalents of the latites. The correspondence however is not quite perfect, as the two analyses show a slight deficiency in lime and a small excess of alkalies as compared with the mean of the latite analyses. Iddings* states that the rocks of these two analyses belong to the banakite series "both mineralogically and chemically, but are somewhat more siliceous, having 5 to 9 per cent more silica. They might properly be given specific names, but at present we prefer to class them with banakite, under the name *quartz-banakite*, the amount of quartz, however, being very small."

The banakites are intermediate rocks in a similar sense that the latite are intermediate. Chemically they have a rather close analogy with the latter rocks, although somewhat lower in silica, and thus tending through leucitic facies toward the truly alkaline groups of igneous rocks. It is interesting to note that Iddings† remarks in this series the tendency toward mineralogical diversity with nearly identical chemical composition, already emphasized in the case of the latites.

In the succeeding columns of the table are placed the analyses of some monzonites, quoted from Brögger, in order to show the close relationship between these rocks and the effusive latites. Washington, has already pointed out this chemical correspondence in the case of his vulsinites and ciminites,‡ and notes as well analogies with the absarokite-banakite series of Iddings.§

Since the paper, of which the foregoing is an abstract, was written, Washington's final contribution‖ on the Italian volcanic regions has appeared, in which he divides the rocks between the trachytes and andesites into two series,—the *trachyandesites* and the *trachydolerites*, using the former term in a more restricted sense than in his earlier papers. The Sierra Nevada latites would fall most nearly within his trachydolerite series, although not strictly the equivalents of any of its

* Absarokite-Shoshonite-Banakite Series; Journal of Geology, vol. iii, pp. 949–950.

† Absarokite-Shoshonite-Banakite Series; Journal of Geology, vol. iii, p. 951.

‡ Journal of Geology, vol. iv, p. 832.

§ Ibid., p. 838.

‖ Ibid., vol. v, pp. 349–377.

individual members. Whether some such single term as that here proposed shall be used to designate the rocks midway between the trachytes and andesites, or whether it will be found practicable to divide them into two series, or to revive the old term trachydolerite as Washington has done, may, as the latter suggests, in a slightly different connection be left to the winnowing action of time and usage.

Summary.

The contents of the preceding sections may be very briefly summarized as follows:

The area embraced by the map is a fairly typical transverse strip of the middle, western slope of the Sierra Nevada, having been worn down during the interval between the close of the Jurassic and the beginning of the Miocene to a rough peneplain. During the Miocene the volcanic eruptions began, which, accompanied by a tilting of the peneplain to the southwest, continued to the end of the Pliocene. The first eruptions were rhyolitic in character, followed by the laying down of a great cloaking cover of andesitic breccias and tuffs. The deposition of auriferous gravels both preceded and accompanied the deposition of volcanic material.

The accumulation of the andesitic breccias and tuffs was interrupted by at least one period of considerable erosion, during which a long, consequent stream, the predecessor of the Stanislaus River, established its channel down the slope, cutting down through the volcanic accumulations into the older, truncated "Bed-rock series" along the greater part of its course, and ultimately attaining a very regular grade. This stream was subsequently displaced by a heavy flow of augite-latite, the Table Mountain flow, which coming from an as yet unknown source near the crest of the range, ran down the stream bed to Knight's Ferry, near the edge of the Great Valley, a distance of more than 60 miles. A second and thinner flow followed, of augite-biotite-latite, attaining a greater lateral extent, but not so long as the first flow. The third or Dardanelle flow, of augite-latite, closed the series of latitic eruptions. The volcanic period as a whole was brought to an end by fresh andesitic eruptions, as shown by andesitic breccias resting upon the latites, accompanied by further tilting of the peneplain.

During Pleistocene time the present streams have dissected the Neocene lavas and tuffs, including the latitic flows, and have deeply incised the "Bed rock series" of Jurassic and older rocks.

The Sierra Nevada latites are mineralogically closely related

to ordinary andesites, but chemically they stand between the andesites and the trachytes. They are higher in alkalies than the andesites, the potash is generally in excess of the soda, and, *in the particular rocks described*, is present chiefly in the unindividualized glass, where no biotite is present.

Rocks of this intermediate chemical composition are fairly widespread, but characterized by considerable mineralogical diversity. The name latite is proposed as a convenient designation for this entire group of effusive rocks, standing chemically about midway between the andesites and trachytes, and corresponding to the plutonic monzonites of Brögger and possibly to some of the dike banakites of Iddings.

Washington, D. C., March, 1898.

ART. XLVI.—*On Krennerite, from Cripple Creek, Colorado;* by ALBERT H. CHESTER.

THE writer recently received from Messrs. George L. English & Co. a specimen from the Independence Mine at Cripple Creek, Colorado, which shows a number of very distinct crystals of krennerite, a mineral not previously identified from this country. This species was first noticed among minerals from Nagyag in Hungary, and described by Krenner* in 1877, under the name bunsenin. In the same year vom Rath† called it Krennerite after its discoverer. It is an exceedingly rare mineral and has heretofore been found only at the original locality.

The mineral from Cripple Creek occurs in brilliant crystals of a pale yellowish-bronze color, but tin-white on cleavage faces. The largest of these crystals, of which there were originally about thirty on the specimen, are about 2^{mm} in length and the same in breadth, and they are at once recognized as belonging to the orthorhombic system, showing prismatic faces deeply striated, pinacoids and domes, and resembling some forms of arsenopyrite. Some of the crystals show a perfect basal cleavage. The crystallographic examination has been made by Prof. S. L. Penfield, and his results are given later. The mineral is very brittle and has a hardness of about 2·5. Heated on charcoal it decrepitates violently, and fuses easily, burning with the characteristic bluish-green flame of tellurium, and coating the coal with its oxide. A globule of seemingly pure gold finally results. It has therefore the characteristics

* 1877, Term. Füz., Pt. 1.
† 1877, Ak. Ber. Monat., 292.

of krennerite rather than of calaverite, the crystals of which do not decrepitate when heated, have no basal cleavage, and according to Penfield,* are probably triclinic. The crystals now described occur on a quartzite gangue, and are partially imbedded in a thin layer of soft, gray material, which may be kaolinite, but has not yet been examined. Small crystals of pyrite are scattered abundantly through the quartzite gangue.

The chemical examination has been made by my colleague, Prof. W. S. Myers. Three of the crystals were carefully detached, and when cleared as far as possible of all adhering matter, until nothing but crystalline faces could be observed under the magnifier, afforded extremely pure material, as shown by the analysis, the results of which are as follows, tellurium being estimated by difference:

Au	43·33 per cent.
Ag	0·45 "
[Te]	55·01 "
Insoluble	1·21 "
Fe_2O_3	trace.

Deducting the insoluble matter and calculating to one hundred we have,

	Per cent.	Ratio.		
Au	43·86	·223	·227	1·00
Ag	0·46	·004		
Te	55·68	·445		1·97

The ratio of Au+Ag : Te is very nearly 1 : 2, which gives for the formula of the mineral $AuTe_2$, the same as in calaverite and sylvanite, though with less silver than has been recorded heretofore. In this group, however, variations in the amount of silver are very wide, and there is probably no fixed proportion of silver to gold. The present analysis corresponds very closely with that of calaverite from the same locality, by Hillebrand,† and it is very desirable that more crystals of calaverite should be found to settle the question positively as to its crystalline form, for if it is triclinic we have three distinct tellurides of gold and silver, orthorhombic krennerite, monoclinic sylvanite and triclinic calaverite. But it seems more probable that there are only two of these minerals and that calaverite is the silver-free form of sylvanite; for this new analysis, of undoubted krennerite, varies as widely from the earlier ones in its proportion of silver as do the analyses of

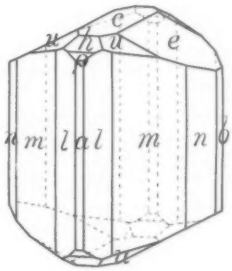
* This Journal, III, l, 131, 1895.
† This Journal, III, l, 128, 1895.

calaverite from those of sylvanite, and as shown by Penfield (l. c.), the calaverite crystals he examined have many characteristics in common with sylvanite. It hardly seems possible that these krennerite crystals are identical with the calaverite described by Hillebrand.

Prof. Penfield's note on the crystallography of this mineral is as follows:

"The crystals of krennerite were not very favorable for crystallographic study, as they were striated and gave generally poor reflections of the signal. Two crystals having the habit represented by the accompanying figure were measured, and gave sufficiently accurate measurements for the identification of the forms, which correspond to the prominent ones identified by vom Rath* and Schrauf.† The forms are as follows:

a,	100	*l*,	320	*h*,	101	*u*,	122
b,	010	*m*,	110	*ρ*,	201		
c,	001	*n*,	120	*e*,	011		



The following measurements were made:

		Measured.	Calculated.
$a \wedge l$,	$100 \wedge 320$	32° 25′	32° 5½′
$a \wedge m$,	$100 \wedge 110$	43 30	43 15
$a \wedge n$,	$100 \wedge 120$	61 55	62 0½
$a \wedge h$,	$100 \wedge 101$	61 22	61 48
$a \wedge \rho$,	$100 \wedge 201$	42 55	43 0
$e \wedge e$,	$011 \wedge 0\bar{1}1$	54 15	53 32
$u \wedge u$,	$122 \wedge \bar{1}22$	26 43	26 55½

The perfect basal cleavage is a prominent feature of the mineral."

Rutgers College, March 28th, 1898.

* 1877, Zeitsch. Kryst., i, 614. † 1878, Ibid., ii, 235.

ART. XLVII.—*Some new Jurassic Vertebrates from Wyoming.* Second Paper by WILBUR C. KNIGHT.

THE University of Wyoming has in its collection of Jurassic vertebrates partial remains of four swimming saurians, that in a general way resemble plesiosaurs. The discovery of these remains is of considerable value to American Mesozoic geologists, for these data will be very valuable in correlating the American and European Jurassic. It is of equal importance in separating the term Jura-Trias, and making American Jurassic and Triassic terranes, in the place of the consolidated term that has been in use since the early surveys in the Rocky Mountains. The largest of these four species surpasses in size the European Pliosaur, and owing to the many peculiar characters it has been deemed necessary to create a new genus.

Megalneusaurus gen. nov.

Vertebra over two-thirds as long as wide; height of the centra nearly equalling the transverse diameter. Anterior cervical vertebra deeply cupped anteriorly and slightly concave posteriorly; neural arches united by suture and always found detached. Dorsal vertebra cylindrical with a forward overhanging of the upper part of the centra; anterior faces slightly concave, posterior flat; both faces with mammilla; zygapophyses spoon-shaped; neural arches firmly sutured to centra; neural spines low and nearly as long as the centra. Caudle vertebra with slightly concave faces and mammilla. Coracoids produced in front of the glenoid cavity. Joints of the digits alternate with each other. Phalanges concave proximally, convex distally. Ulna and radius short, broad, heavy bones, nearly equal in size, and separated by a small central opening. Below this opening the two bones are united by rugose surfaces; above they are united by a horn-like projection extending from the ulna and fitting into a depression in the radius. Ulna concave proximally and convex distally. Radius, inner one-fourth of the proximal end concave; outer three-fourths convex. Carpal bones six in number and all angular. Humerus a powerful bone with a prismatic shaft; distally broad and flat; proximally expanded into a spherical head. The anterior side of the head of humerus with a groove; the posterior side with a broad shallow indentation. This genus in many respects resembles Pliosaurus, but it also has characters that are common to Peloneustes and Plesiosaurus. It represents the largest known animals of the order Sauropterygia.

Megalneusaurus rex Knight.*

The type of this genus and species has been founded upon the following remains: Cervical, dorsal and caudal vertebra; one limb nearly complete; ribs and the greater portion of the pectoral girdle. The limb measures 2·209 meters in length. When found it was articulated and in the position represented in figure 1. Between the ends of the phalanges were hardened disks of siliceous matter measuring 10^{mm} in thickness. The phalanges are long cylindrical bones with rather slender shafts and expanded ends. The shape and size of these bones vary greatly when belonging to the same row. For example, the first phalange of the first digit is 87^{mm} long, and the first phalange of the fifth digit is 106^{mm} long. The first digit is coalesced with the second at the fifth joint of the second. The metacarpal of the fifth digit articulates with the ulnare and the third bone of the distal row of carpals. The radius has a groove extending two-thirds of the length of the exterior border. Radial likewise grooved. The coracoids are long, broad bones, but are not in a condition to give valuable measurements. The vertebra vary greatly in form: cervicals, truncated above, with nearly straight sides which gradually curve and form a rounded lower surface; dorsals, cylindrical, slightly compressed, with large transverse processes; neural spines low and keel shaped; caudals, flattened beneath.

Measurements.

Humerus,—	Length	·991^{m}
	Distal width	·365
	Distal thickness	·122
	Thickness of shaft	·195
	Circumference of shaft	·555
	Proximal width	·225
	Proximal height	·266
	Proximal circumference	·875
Ulna,—	Width	·178^{m}
	Length	·158
	Distal thickness	·080
	Proximal thickness	·104
Radius,—	Width	·171^{m}
	Length	·163
	Distal thickness	·100
	Proximal thickness	·100
Ulnare,—	Width	·130^{m}
	Length	·095
	Thickness	·088
Intermedium,—	Width	·100^{m}
	Length	·140
	Thickness	·078

*Cimoliosaurus rex., Science, Oct. 4, 1895, p. 449.

Radiale,—Width	·135^{m}
Length	·085
Thickness	·088
First distal carpal,—Width	·111^{m}
Length	·078
Thickness	·067
Second distal carpal,—Width	·140^{m}
Length	·100
Thickness	·067
Third distal carpal,—Width	·100^{m}
Length	·100
Thickness	·058

First row of basal phalanges.

	No. I.	No. II.	No. III.	No. IV.	No. V.
Length	87^{mm}	102^{mm}	106^{mm}	106^{mm}	106^{mm}
Proximal width	52	70	68	62	42
Distal width	52	60	65	50	40
Width through shaft	32	37	35	31	25

A cervical vertebra centrum,—Width	·080^{m}
Length	·065
Height	·078
A drosal vertebra centrum,—Width	·152^{m}
Length	·111
Height	·150
A caudal vertebra centrum,—Width	·103^{m}
Length	·077
Height	·065

The remains of this species were found in Natrona County, by the writer. The geological position is the uppermost band of the marine beds of the Jurassic. I would suggest that hereafter these marine beds be known as the Como group. I take this opportunity to thank Dr. Baur and Dr. Williston for many suggestions in connection with this paper.

University of Wyoming, March 28th, 1898.

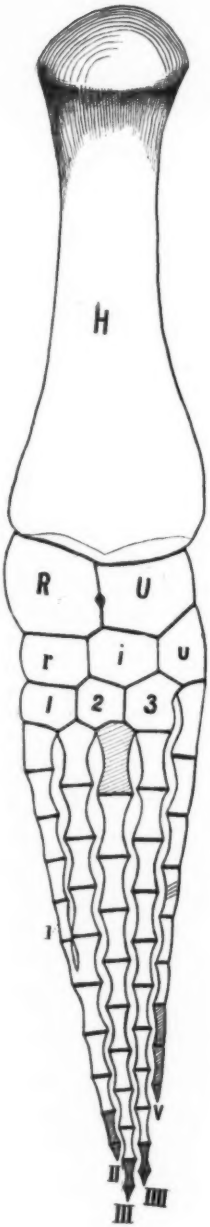
EXPLANATION OF FIGURES.

Fig. 1.—Front limb of *Megalneusaurus rex*. $\times \frac{1}{12}$. H, humerus; R, radius; U, ulna; *r*. radiale; *i*, intermedium; *u*. ulnare; 1, 2, 3, distal row of carpals.

Fig 2.—Side view of humerus, showing the development of the head, $\times \frac{1}{3}$.

Fig. 3.—Cross-section of the head of the humerus. $\times \frac{2}{3}$.

1.



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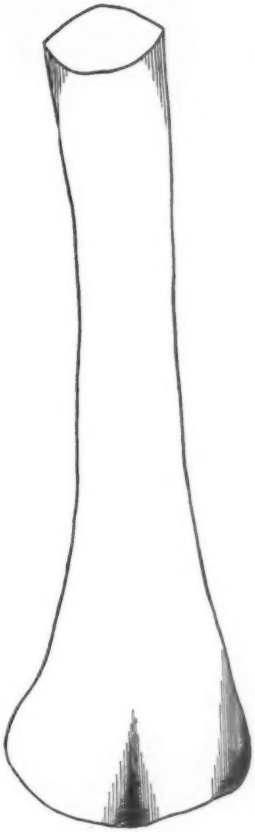

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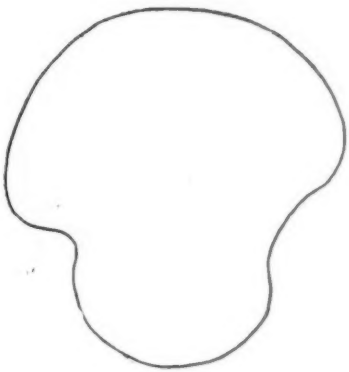

Art. XLVIII.—*On the Estimation of Manganese separated as the Carbonate;* by Martha Austin.

[Contribution from the Kent Chemical Laboratory of Yale University—LXIX.]

The estimation of manganese precipitated as the manganous carbonate, when that salt is obtained by the action of sodium or potassium carbonate, has been regarded as very undesirable for the reasons that, even if the conditions of the precipitate is such that it does not run through the filter, the manganous carbonate can never be freed entirely from alkaline salt, and that the conversion of the carbonate to the manganoso-manganic oxide—the form in which it is customary to weigh—is too uncertain. It had been supposed, also, that the presence of ammoniacal salts (as well as of carbonic acid) causes solution of the manganous carbonate, until the work of Guyard (Hugo Tamm)* showed that when the precipitation is accomplished by ammonium carbonate, even in the presence of ammonium chloride, complete separation of the manganese is possible. No data are given by Guyard to show the completeness of the separation of the manganese by this process; but, Fresenius† examined the method and speaks favorably of it. In this process the main difficulty of the older method of estimation as the carbonate—viz., the inclusion of the alkaline salt—is avoided. We know now how to avoid the difficulty in the way of weighing as the oxide by converting that substance to the form of the sulphate, as shown in a former paper.‡

For a careful study of the separation of manganous carbonate by Guyard's method a solution of pure manganous chloride was prepared and standardized as the anhydrous sulphate in the manner detailed in the paper to which reference has been made above. A definite volume of the manganous chloride was carefully drawn into a platinum dish and diluted to a volume of 200^{cc}. To the solution heated to 100° C. ammonium chloride (about 10 grm.) was added and ammonium carbonate in excess. The solution was kept warm until the precipitate subsided, and then was filtered off on asbestos on a perforated crucible under pressure. The presence of ammonium chloride is necessary to insure such a condition of the precipitate that it will not run through the felt.

Inasmuch as the precipitate was collected under conditions which readily permit an attempt to weigh as the carbonate, a trial of that method was made incidentally. The event proved

* Chem. News, xxvi, 37.

† Zeit. f. Anal. Chemie, 1872, 290.

‡ This Journal, IV, v, 209.

as Rose* has stated previously, that when the carbonate is gently heated, evolution of carbon dioxide and oxidation of the residue begins before the water is thoroughly removed; for, though nearly all the results are above the theory, the solution of the residue in hydrochloric acid indicated plainly the presence of a small amount of a higher oxide of manganese. In the following table are found the results of a series of experiments in which the attempt was made to weigh first as carbonate and again after strong ignition—well within the oxidizing flame of a powerful burner†—as the manganoso-manganic oxide. The application of the bromine test to the hot ammoniacal filtrate showed, that in every one of these experiments, the precipitation of the manganese in the form of the carbonate had been complete.

$MnCl_2$ cm^3.	MH_4Cl grm.	$MnCO_3$			Mn_3O_4		
		Found.	Theory.	Error.	Found.	Theory.	Error.
50	10	0·2685	0·2680	0·0005 +	0·1770	0·1776	0·0006 —
50	10	0·2704		0·0024 +	0·1788		0·0012 +
50	10	0·2710		0·0030 +	0·1770		0·0006 —
50	10	0·2720		0·0040 +	0·1774		0·0002 —

As shown in this table, weighing as the carbonate is out of the question; the errors of the process when the residue is ignited in the manner described to form the manganoso-manganic oxide are much smaller though rather variable. The estimation of manganese as the anhydrous sulphate had given in the work to which reference has been made results agreeing so much more closely than could be obtained by any other method of procedure, that the attempt was made to estimate the amount of manganese precipitated as the manganese carbonate by converting it first to the oxide, then to the sulphate. A given weight of sulphate was precipitated as the manganous carbonate, after the employment of all the precautions mentioned previously in this paper, and then filtered off on ashless filter paper. After washing thoroughly with hot water, the filter was burned, the residue ignited for the condition of the manganoso-manganic oxide and weighed as such. Then the oxide was converted to the sulphate by heating with three or four drops of concentrated sulphuric acid. The agreement of the results as shown in the following table is considerably better.

* Annal d. Phys. u. Chem., 1851, lxxxiv, 52.
† This Journal, IV, v, 209.

	MH_4Cl grm.	Mn_3O_4 Found.	Mn_3O_4 Theory.	Mn_3O_4 Error.	$MnSO_4$ Found.	$MnSO_4$ Theory.	$MnSO_4$ Error.
(1)	10	0·2463	0·2478	0·0015—	0·4903	0·4905	0·0002—
(2)	10	0·1110	0·1121	0·0011—	0·2225	0·2219	0·0006+
(3)	10	0·1584	0·1581	0·0003+	0·3126	0·3128	0·0002—
(4)	10	0·1672	0·1699	0·0027—	0·3355	0·3364	0·0009—

By treatment of the filtrates of (1), (2) and (3) with bromine and ammonia at boiling temperature no manganese was found. In the filtrate from number (4) by the same treatment, a small amount of manganese dioxide was precipitated, which when heated with concentrated sulphuric acid gave 0·0006 grm. of manganous sulphate; and, hence, the error in that determination is really 0·0003 grm. on the sulphate. The slightly larger deficiency recorded in the table was probably due to imperfect filtering.

It seems to be evident that Guyard's method of separation of manganese as the manganous carbonate, when handled with precautions, gives complete separation of that element. It must be recognized clearly, however, that the precipitation should be made in the presence of a considerable amount of ammonium chloride, and that great care must be used in the filtering and washing of the finely divided precipitate. It is altogether preferable to weigh in the condition of the sulphate.

In conclusion thanks are hereby expressed to Professor F. A. Gooch for kind assistance.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On New Methods for Measuring Gases.*—Several methods for measuring gases have been described by Blair, which seem to present important advantages. In the first, which is a new compensation method, it is the gas under examination, and not the standard gas with which it is to be compared, which is kept at constant volume or is adjusted to a known fraction of the original volume. In the apparatus used for air analysis, the whole is surrounded with a water jacket. It consists of two tubes A and B; A being filled with the gas to be tested and B with the standard volume. The tube B has a cylindrical bulb at its top of a capacity of 100^{cc}, the tube itself below this holding 1^{cc} and being graduated to $0{\cdot}01^{cc}$. The parallel tube A has a $79{\cdot}5^{cc}$ cylindrical bulb at its top and just below it a second bulb of $20{\cdot}5^{cc}$. After filling both tubes to the 100^{cc} mark at the atmospheric pressure, their upper ends are connected by means of taps with a re-curved capillary tube having a drop of liquid in the bend. Since the pressure is the same in the two tubes, the drop will remain in the center when the taps are opened. The carbon dioxide is then absorbed, the liquid is brought to its original level in the two tubes and the taps are opened. Since the absorption has slightly decreased the pressure in A, the drop moves to that side. The liquid in B is then lowered by lowering the reservoir connected to the ends of both tubes by a rubber hose, until the drop comes back to the center. If to do this the level of the liquid in B has been lowered $0{\cdot}15^{cc}$, the percentage of CO_2 is $0{\cdot}15 \times (100 / 100{\cdot}15)$ Next the oxygen is absorbed and the process is repeated, except that the liquid in A is brought to the upper level between the two bulbs in place of the lower level. If the final level is $0{\cdot}53^{cc}$ the percentage of oxygen is $20{\cdot}5 + 0{\cdot}53 \times (79{\cdot}5 / 100{\cdot}53)$. In this way very great accuracy is secured, all the measurements being made under nearly the same pressure, though each special gas requires specially divided tubes. Evidently this same apparatus can be used with the ordinary compensation method by placing the gas to be examined in B, which it completely fills; the standard gas volume being contained in A. Indeed a combination of the two may be employed using the second method first and then the first method. In a second method the measurements of volume are made by means of pressure readings. A pipette consisting of five bulbs is made use of, inclosed in a water jacket. Each bulb has an approximate capacity of 20^{cc} and on the connecting tubes between each pair of bulbs a mark is made, the volume of the pipette down to each mark being accurately known. Besides this pipette a graduated manometer tube is provided, connected with a movable reservoir, which tube is clamped in position and reaches to about 60^{cm} above and below the lowest mark of the pipette;

marks being drawn on the manometer to correspond to those on the pipette. The gas is first compressed to the lowest mark and the pressure is noted on the manometer. The absorption of one constituent is then proceeded with and the pressure is again noted, the volume being adjusted to the same mark, or if this is not possible to the one above it. Finally the author describes a measuring pipette with reserve spaces. It consists of two parallel vertical branches enclosed in a water jacket. One of these branches is a cylindrical tube holding 20^{cc} and graduated. The other consists of four bulbs having a mark on the constriction below each bulb; the volume between each of these marks and the upper graduation on the first tube being accurately known. A connecting tube provided with a tap joins the two tubes at top. At bottom these tubes are connected with a movable reservoir by means of rubber hose and a three-way tap. In making a measurement the liquid is driven up to a convenient mark, the rubber tube is closed by a spring clip, and the reservoir is adjusted so as to bring the level of the liquid in it to the same point as in the graduated branch of the pipette; the volume of the gas may then be read directly. —*Ber. Berl. Chem. Ges.*, xxx, 2753–2759, 1897. G. F. B.

2. *On the Influence of the Röntgen Radiation on the Velocity and Rate of Recombination of the Ions of Gases.*—It is well known that air which has been exposed to Röntgen radiation retains the power of discharging positive and negative electrification for a short time after the rays have ceased. RUTHERFORD has investigated the duration of this after-conductivity in the case of air and other gases and from the data thus obtained has determined the velocity of the ions through various gases. These are given in the following table, in which T represents the time required for the number of ions to fall to one-half their original value.

Gas.	T in seconds.	Conductivity, Air = 1.
Hydrogen	0·65	0·5
Air	0·3	1
Hydrogen chloride	0·35	11
Carbon dioxide	0·51	1·2
Sulphurous oxide	0·45	4
Chlorine	0·18	18

Apparently there is no very close relation between the values of T and the conductivities, though in general the value of the former diminishes as the latter increases. For the same gas the value of T was observed to depend largely on the intensity of the radiation. It was also noted that the duration of the after-conductivity was affected by the presence of finely-divided matter either solid or liquid. The author found that the velocities of the ions were independent of the amount of ionization of the gas used, and were inversely as the densities with the single exception of chlorine. The velocity of the hydrogen ion through hydrogen was observed to be nearly four times as great as that of the oxy-

gen ion in oxygen. The ions of sulphurous oxide gave the slowest velocity, only one-tenth that of hydrogen.—*Phil. Mag.*, V, xliv, 422–440, November, 1897. G. F. B.

3. *On the Connection between Fluorescence and Chemical Composition.*—According to R. E. MEYER, the fluorescence of organic compounds may be considered to be due to the presence of certain atomic groups, which undergo no change in the several fluorescent derivatives of a given substance. These groups the author proposes to call fluophores or fluophoric groups. But in order that there should be an actual fluorescence, the fluophore must be placed between two massive atomic groups, usually benzene nuclei. Thus in the derivatives of fluoran which embrace the fluoresceins, naphthofluorans, rhodamines and the like, the fluophore is the pyrone group which although not itself fluorescent becomes so in the diphenyl derivatives. The same fluophore is contained in the xanthones, while in the xanthens its reduction product is present; the effect of substitution being very marked. It may be said that in general the entrance of heavy atoms or groups into the benzene nuclei decreases the fluorescence, the nature and position of the substituted body influencing the result very largely. The presence of hydroxyl groups for example in any position other than that of the fluorescein hydroxyls may greatly weaken or even destroy the fluorescence of the fluoran and xanthone compounds. Only the direct derivatives of the anthracene group and not anthraquinone are fluorescent. The fluophore in the acridine compounds is . In this case the effect of the position of the substituted body is very marked, since benzoflavine, which has both its amido groups in the "fluorescein position," is far more strongly fluorescent than its isomer chrysaniline. If sulphur be substituted for oxygen in the pyrene ring, the fluorphoric character is not destroyed, the thiopyrene derivatives showing a weak fluorescence. Moreover the azine, oxazine and thioazine rings act as fluophores in the phenazines, phenazoxines and thiodiphenylamine compounds, which include many important fluorescent dyes, as mauveine, the safranines and allied naphthalene compounds, the indulins, Lauth's violet, and methylene blue; this latter showing a reddish-violet fluorescence. The influence of the solvent is also important.—*Zeitschr. physikal. Chem.*, XXV, 468–508, December, 1897. G. F. B.

4. *On a new method of preparing pure Iodine.*—Some months ago LEAN and WHATMOUGH observed that no iodine was set free when cuprous iodide was heated even to fusion in a current of carbon dioxide, while it is well known that iodine is readily evolved from this substance when it is heated in the air, even to a moderate temperature. They have based on this fact a method for preparing perfectly pure iodine. For the preparation of the cuprous iodide, a solution of a mixture of copper sulphate and ferrous sulphate was precipitated by a solution of potassium iodide; a pure product being obtained by proper dilution. This cuprous

iodide was then heated until fused in a current of dry and pure carbon dioxide in order to drive off hydrogen iodide and moisture; after which the iodide was heated in a current of dry air to between 220° and 240°. A continuous stream of violet vapor was carried forward and condensed in beautiful crystals in the cooler parts of the tube. To test the purity of the iodine so obtained 2·7529 grams was placed in a tube and heated to 75° in a slow current of dry air. After 4 hours only a slight brown residue remained, weighing 0·3 milligram; this proving afterward to have come from impurities in the air. No copper could be detected in it by the spectroscope. The fusing point of this iodine was 112·5°–114°. It is blacker than the ordinary iodine.—*J. Chem. Soc.*, lxxiii, 148–157, March, 1898. G. F. B.

5. *On the Borides of Calcium, Barium and Strontium.*—An investigation has been made by Moissan and Williams on the preparation and properties of the borides of calcium, barium and strontium. Calcium boride is readily obtained by heating in a carbon crucible a mixture of 1000 parts of calcium borate, 630 parts of aluminum and 200 parts of sugar carbon, for seven minutes by means of a current of 900 amperes and 45 volts. The calcium borate is completely reduced by the aluminum, the carbon preventing the formation of aluminum oxide. The product obtained is broken up and treated first with dilute and then with concentrated boiling hydrochloric acid, water, ether, toluene and hydrofluoric acid. The resulting substance has the composition CaB_6 and forms transparent microscopic crystals, cubic or rectangular in form, which scratch rock crystal and even rubies. Their density at 15° is 2·33. Fluorine in the cold and chlorine at a red heat attack it readily, the former with incandescence. It is not decomposed by water at 250° under pressure, but the gaseous hydracids attack it at a dull red heat. Barium boride prepared similarly has analogous properties. Its crystals are small but very regular, having a density of 4·36 at 15°. They scratch rubies but not the diamond. Strontium boride is not attacked by fluorine in the cold. Its density is 3·28 at 15°.—*C. R.*, cxxv, 629–643, November, 1897. G. F. B.

6. *The Arrangement of Atoms in Space;* by J. H. Van't Hoff. 2d revised and enlarged edition. With a preface by Johannes Wislicenus, and an Appendix, Stereochemistry among Inorganic Substances, by Alfred Werner. Translated and edited by Arnold Eiloart. 12mo, pp. xii, 212. London, 1898. (Longmans, Green & Co.)—Perhaps no book of recent times has had a more profound influence upon structural chemistry than this little volume. It appeared first in 1877 under the title "La Chimie dans l'Espace," and had for its motto a quotation from Wislicenus's paper on lactic acid, published in 1869: "The facts compel us to explain the difference between isomeric molecules possessing the same structural formulæ by the different arrangement of their atoms in space." The new edition, of which the present work is a translation, was issued in 1894, and is to a considerable extent a

union of the original work with van't Hoff's "Dix Années dans l'Histoire d'une Théorie." The central figure in the new theory —suggested by Le Bel as well as by the present author—is the asymmetric carbon atom. To the law of the quadrivalence of carbon, announced by Kekulé, van't Hoff added the hypothesis that the four valences are directed toward the corners of a tetrahedron at the center of which is the carbon atom. The two isomers of Pasteur, of opposite rotatory power, were explained by means of this tetrahedron and its image, the isomerism disappearing when the two groups become identical, through the resulting symmetry and identity of the two tetrahedra. Thus originated the subject of stereochemistry, now so firmly fixed in the science. Even the little remaining opposition to it is directed, as Wislicenus says, against the ultimate basis—against the atomic hypothesis itself—and does not deny that the doctrine of atomic arrangement in three dimensions is a logical and necessary stage, perhaps the final stage, in the chemical theory of atoms. "It has already effected to the full all that can be effected by any theory; for it has brought into organic connection with the fundamental theories of chemistry facts which were before incomprehensible and apparently isolated and has enabled us to explain them from these theories in the simplest way. By propounding to us new problems the hypothesis has stimulated empirical investigation on all sides; it has caused a vast accumulation of facts, has led to the discovery of new methods of observation, has become amenable to the test of experiment and has at the same time started in our science a movement full of significance—in a certain sense indeed a new epoch." In the new edition a section on nitrogen derivatives has been added; in the part devoted to carbon the greatly increased number of facts has been taken into account, and special attention has been given to the amount of rotation of active bodies; thus making it a reference book at once for stereochemistry and optical activity. The translation is an excellent one, as was to be expected from the well known ability of Dr. Eiloart in this direction. G. F. B.

7. *A College Course of Laboratory Experiments in General Physics;* by SAMUEL W. STRATTON and ROBERT H. MILLIKAN, of the University of Chicago. 8vo, pp. IV, 100. Chicago, 1898. (University of Chicago Press.)—This laboratory manual is designed for the students of the Junior College Courses in Physics in the University of Chicago. "The aim has been to select and devise a set of experiments calculated, first to give an acquaintance with the methods and a view of the field of Experimental Physics such as is requisite to a liberal education; and second to train the student to accurate observation, skilful manipulation and logical interpretation of observations." It appears to us that this aim has been realized. Within this hundred pages fifty-three experiments have been described, each excellent in character, clearly and succinctly stated, requiring the use of accurate and simple apparatus, and so performed as to lead

to the best results. The book cannot fail to be of excellent service for the class of Junior students for whom it was prepared, and so is a valuable contribution to the teaching of physics from the admirable Ryerson laboratory. G. F. B.

8. *Text-book of Physical Chemistry;* by CLARENCE L. SPEYERS, Rutgers College. 8vo, pp. viii, 224. New York, 1897. (D. Van Nostrand Co.)—Physical chemistry is here defined as "the science which has for its object the investigation of chemical changes by physical methods." In his preface the author says: "I have adopted the view that matter is a collection of energies in space, considering the relations of the energies to be the prime object of investigation. With Ostwald, I feel confident that the materialistic interpretation has passed its prime and has no promise for the future." "The different forms of matter," he says, "we may define as different collections of activities in space, the quality and quantity of these activities changing with the different forms of matter." And again: "We need energy and a something to enable energy to collect in space before we get a material substance. This something which enables and perhaps causes the energy to collect in space we shall call matter." So that it would appear that matter has two definitions: first "a collection of energies," and second, a "something," an unknown entity which causes these energies thus to collect; the latter being not very unlike our present conception. Moreover "the belief that oxygen and hydrogen still persist as such in water, and in general the idea that the elements persist in a compound," is not justifiable. "All we may assume is that the conditions that *cause* the breaking up of a collection require the formation of those collections which went to make up the collection just destroyed. But to claim that these collections originally existed in the collection that broke up, is entirely opposed to the evidence of our senses." It will be seen from these quotations that the author follows Ostwald pretty closely even when he is most radical; sometimes even surpassing him. Thus he uses time, space and energy as his fundamental units; but he denounces the kinetic theory of gases as "a troublesome thing" which "is becoming an object of ridicule." Nevertheless the book will serve a useful purpose. It contains in compact form excellent chapters on energy, gases, heat, physical changes, equilibrium, chemical kinetics, phases, variable temperature, electrochemistry and ions. The problems are a valuable addition to the text. G. F. B.

9. *The Tutorial Chemistry. Part II. Metals;* by G. H. BAILEY, Ph.D. Edited by William Briggs, M.A. 12mo. pp. viii, 300. London, 1898 (W. B. Clive).—This little book treats of the metallic elements in much the ordinary way, except that a more considerable space is given to chemical physics than is usual in manuals of this grade. The grouping follows the order of the periodic system and in an appendix is given a chapter on crystallography, one on spectrum analysis and a third on a series of useful experiments. The book will prove of value, we think, for second year students.

10. *The ultra red spectrum.*—Professor Langley has shown that the energy in the ultra red spectrum of sunlight falls off very rapidly and beyond $\lambda = 5\mu$ the energy is only measurable at certain points. This remarkable fall of energy in sunlight compared with that of other sources of light Langley attributes to the absorption of the earth's atmosphere. H. Rubens and E. Aschkinass have studied this question of absorption by means of the method used by H. Rubens in previous researches. (H. Rubens and E. F. Nichols, Wied. Ann., lx, p. 418, 1897.) This method consisted in using repeated reflections from surfaces of sylvite in order to obtain homogeneous rays of great wave length. These rays were sent through layers of carbonic acid gas and of water vapor, and it was discovered that the earth's atmosphere must be non-transparent for rays of wave length 12–20μ as well as for rays of wave length $24{\cdot}4\mu$. Langley's investigations were made with a rock salt prism of 36°. This enabled him to investigate the region up to 10–11μ. The authors state that the fact that beyond the region $\lambda = 12\mu$ the sun's rays are absorbed is of small importance in practical meteorology since the energy of these rays is small compared with that of the entire amount of emission of the sun.— *Wied. Ann.*, No. 3, 1898, 584–601. J. T.

11. *Transparency of fluids for heat rays of great wave length.*—By means of a method of obtaining heat rays of great wave length, H. Rubens and E. Aschkinass have shown that the absorption of long heat rays by means of water is very great. The index of refraction of water for these rays is of the same order of dimension as for the visible spectrum, and the high value $\lambda = 9$ obtained for Hertz vibrations must lie beyond 24μ. It was found that benzol was more transparent for the long waves of heat than hitherto investigated substances. Bisulphide of carbon showed a comparatively small absorption, and xylol a marked transparency. The authors point out that these two substances together with chloride of silver belong to that class of substances for which, according to the extrapolated Cauchy formula applied to infinitely long wave lengths, the square of the index of refraction is approximately equal to the dielectric constant.— *Wied. Ann.*, No. 3, 1898, 602–605. J. T.

12. *Electrical resistance standards.*—W. Jaeger and K. Kahle give a careful discussion of the results reached at the Reichsanstalt upon the tests of constancy of resistance standards. It was found that the constancy of the manganine wire standards was remarkable. Between January, 1895, and June, 1897, the change in resistance of the standards was in the hundred thousandth place.— *Wied. Ann.*, No. 3, 1898, 456–485. J. T.

13. *Electric equilibrium between uranium and an insulated metal in its neighborhood.*—Lord Kelvin with several students has shown that a sheet of metallic uranium can disturb the electric equilibrium in the neighborhood of an insulated metallic plate. An insulated metallic plate was connected to the insulated pair of quadrants of an electrometer. When the metallic uranium was

placed opposite the insulated metallic plate, the electrical equilibrium was destroyed and a deviation of 84 scale divisions was obtained from the electrometer. A plate of brass or other metal produced no effect.—*Phil. Mag.*, March, 1898, 277–278. J. T.

II. Geology and Mineralogy.

1. *L'échelle réduite des expériences géologiques permet-elle leur application aux phénomènes de la nature?* Par W. Prinz. (Revue de l'université de Bruxelles, tome II, pp. 550–547, figs. 1–49. 1897.)—Professor Prinz in this paper has brought together a series of experiments to show the close similarity of the effects produced by a variety of modes of application of mechanical pressure upon various substances differing very greatly in dimensions and in physical consistency. The experiments of Daubrée and James Hall, and later of Cadell and Willis and others, with clay and wax models of geological strata, are familiar to all geologists. The folding and faulting of mountain regions are thus reproduced on a small scale. The experiments of Malloc are cited to show that the materials of the thin layer of steel, removed from the surface as the tool advances in a planing machine, behave in the same way as do the wax and clay models, and likewise the rock layers in faulting and sliding over each other.

The law that cleavage planes form at oblique angles, and schistosity planes at right angles to the direction of the compressing force, is illustrated by geological sections, by cylinders of wax and clay, by the fractures appearing in a pile of setting and settling mortar, by the cracking of walls broken by the jar of earthquake; and complex effects produced by bending an elongated cylinder of clay illustrate the same principle. The relation of the direction of the planes of fracture to the duration of the passage of the pressure is illustrated by another series of experiments bringing out the fact that the relationship between these two factors is independent of the nature of the material and of the size of the fractures.

The familiar crevasses of glaciers are first put in evidence. The same law is traced by the author through the following diverse experiments: The cracks diverging from a line made by drawing a cane through the snow, a needle drawn across a thin layer of plaster, a pencil in raggedly tearing a sheet of paper, a stick drawn through the mud of a road. Added to these are the effects produced by a steel roulette used in cutting glass, the like effect of a cart-wheel running through a muddy road. Microscopic examination of the scratch of a diamond upon a glass plate shows the same disposition of the fracture planes as in the other cases.

In these several cases it appears that the fractures produced in substances of greatly varying constitution, when pressed beyond the limit of elasticity by a hard tool either passing through it, pressing over the surface, or rolling on the surface, are alike in

diverging from the line of pressure obliquely forward. These fractures, in other words, converge toward the direction of the source of the pressure. The paper is well illustrated and is full of suggestions for structural geologists. H. S. W.

2. *Geological survey of the Witwatersrand, Southern Transvaal;* by FREDERICK H. HATCH. (Quar. Jour. Geol. Soc., liv., pp. 73–99, 1898.)—The geological structure of this South African gold region has been studied by Dr. Hatch during his occupation in the district as a mining engineer, and in the present article a résumé of what is known is clearly presented with diagrams and map. The Cape system, which rests upon the Archæan, and is followed by the Karoo system, or Coal Measures of this region, constitutes the main body of rocks illustrated. The author finds the Cape system to consist of about 50,000 feet of beds, made up as follows:

Magaliesberg and Gatsrand series	16,000 to 20,000 ft.
Dolomite Formation	6,000 " 8,000 "
Black Reef Formation	20 " 50 "
Klipriversberg Amygdaloid	5,000 " 6,000 "
Witwatersrand Beds	11,000 " 15,000 "
Hospital Hill series	8,000 " 10,000 "

H. S. W.

3. *Revised Text-Book of Geology by James D. Dana;* edited by WM. NORTH RICE. 5th edition, revised and enlarged. pp. 1–482, figs. 1–464, 1898. (American Book Company.)—With the increased size of the Dana's "Manual," such a book as this is demanded for general classes, both in high schools and colleges when an elementary, and not a complete technical knowledge of geology is sought. The late author having completed with great pains the "Manual," was at work upon the revision of the Text-Book nearly up to the time of his death. Professor Rice, who was a pupil of the author, has finished the task, carefully revising the whole, with full appreciation of the spirit of the original, which he has preserved with a loyal devotion. A few modifications are made, bringing the nomenclature and classifications into harmony with common usage of the present date.

"In the present edition, the bearing of various events in geological history upon the theory of evolution is pointed out, in the appropriate places; and in the closing chapter, which has been entirely rewritten, the general bearing of paleontology upon evolution is discussed." Some change has been made in the treatment of the history of the Quaternary, and in the discussion of Metamorphism the editor has departed from the views held by the author. We also notice some changes in the order of discussion of the divisions of the subject. Taken as a whole, the present edition is well adapted to hold the same place of preëminence which the earlier editions, prepared by the author's own hand, have continuously occupied. H. S. W.

4. *On the genus Lepidophloios,* as illustrated by specimens from the Coal formation of Nova Scotia and New Brunswick; by

Sir J. Wm. Dawson. (Trans. Roy. Soc., Canada. 2d ser., vol. iii., sec. iv., pp. 57–78, plates 1–xiv, 1897.)—The author brings together in the present paper a full account of what is known regarding the structure and affinities of the two species of this genus (L. Acadianus and L. Cliftonensis), already described by him, and illustrates the subject with beautiful half-tone reproductions of the remarkable specimens contained in his collection, now deposited in the Peter Redpath Museum, McGill University.

H. S. W.

5. *The Geological Survey of Georgia;* W. S. Yeates, State Geologist.—Two bulletins of the Georgia Geological Survey have recently appeared: of these bulletin No. 3–A is entitled: A Preliminary Report on a part of the Water-powers of Georgia, compiled from the notes of C. C. Anderson, late Assistant Geologist, and from other sources, by B. M. Hall, Special Assistant. 1896. (150 pp.) This report gives an account of the various water-powers of the State, most of which are at present entirely unutilized. The rapidity of the development, however, in the direction of manufacturing has directed attention to the subject, so that the information now brought together is likely soon to bear fruit.

Bulletin No. 5–A is entitled: A Preliminary Report on a part of the Phosphates and Marls of Georgia, by S. W. McCallie, Assistant Geologist. 1896. This report gives the results of investigations made in the counties lying along the Georgia–Florida State line. As the result of these, it is stated that it is improbable that there are, except perhaps in Thomas County, deposits of phosphate of sufficient extent and purity to be mined with profit. Attention, however, is called to the more or less extensive beds of marl or low grade phosphate, and the opinion is expressed that in many, if not all, of these counties deposits exist more or less extensive, which equal in many respects the green sands of New Jersey. The development and use of these deposits, it is thought, would lead to the restoration of thousands of acres of land exhausted by long cultivation, to their original fertility.

6. *Geological Survey of India—Paleontologica Indica.*—The following additions have recently been made to this important paleontological series:

Series XV. Himaláyan Fossils. Vol. I, Pt. 4.—The Permian fossils of the Productus shales of Kumaon and Gurhwal, by Carl Diener, Ph.D. Plates I to V.

Ser. XV. Vol. II, P. 1.—The Cephalopoda of the Lower Trias, by Carl Diener, Ph.D. Plates I–XXIII.

Ser. XVI. Fauna of Báluchistan. Vol. I, Pt. 2.—The Fauna of the (Neocomian) Belemnites beds, by Fritz. Noetling, Ph.D., F.G.S. Plates I, II.

Ser. XVI. Vol. I, Pt. 3.—Fauna of the Upper Cretaceous (Maëstrichtien) beds of the Mari Hills, by Fritz. Noetling. Plates I–XXIII.

III. Miscellaneous Scientific Intelligence.

1. *Report of the National Academy of Sciences for the year* 1897.—This publication, besides the usual matter referring particularly to the Academy itself, contains the valuable report of the Commission appointed by the Academy upon a policy for the forested lands of the United States. This contains much that is new and interesting, giving the results of the observations made by the members of the Commission themselves throughout the west, as well as of their study of forestry methods in other countries. From the report we quote here the conclusions and recommendations with which it closes :

"The Secretary of the Interior, in his letter of February 15, 1896, asked the Academy whether 'it is desirable and practicable to preserve from fire and to maintain permanently as forest lands those portions of the public domain now bearing wood growth for the supply of timber.'

Your committee is of the opinion that it is not only desirable but essential to national welfare to protect the forested lands of the public domain, for their influence on the flow of streams and to supply timber and other forest products; and that it is practicable to reduce the number and restrict the ravages of forest fires in the Western States and Territories, provided details from the Army of the United States are used for this purpose permanently, or until a body of trained forest guards or rangers can be organized. It does not believe that it is practicable or possible to protect the forests on the public domain from fire and pillage with the present methods and machinery of the Government.

In answer to the second question submitted by the Secretary of the Interior, "How far does the influence of forests upon climate, soil, and water conditions make desirable a policy of forest conservation in regions where the public domain is principally situated?" it is the opinion of your committee that, while forests probably do not increase the precipitation of moisture in any broad and general way, they are necessary to prevent destructive spring floods, and corresponding periods of low water in summer and autumn when the agriculture of a large part of western North America is dependent upon irrigation.

The answer to the third question,, "What specific legislation should be enacted to remedy the evils now confessedly existing?" will be found in the series of proposed bills appended to this report. They present the following recommendations :

(1) That the Secretary of War, upon the request of the Secretary of the Interior, shall be authorized and directed to make the necessary details of troops to protect the forests, timber, and undergrowth on the public reservations, and in the national parks not otherwise protected under existing laws, until a permanent forest bureau in the Department of the Interior has been authorized and thoroughly organized.

(2) That the Secretary of the Interior shall be authorized and

directed to issue the necessary rules and regulations for the protection, growth, and improvement of the forests on the forest reserves of the United States; for the sale from them of timber, firewood, and fencing to actual settlers on and adjacent to such reserves, and to the owners of mines legally located in them for use in such mines; for allowing actual settlers who have no timber on their own claims to take from the reserves firewood, posts, poles, and fencing material necessary for their immediate personal use; for allowing the public to enter and cross the reserves; for granting to county commissioners rights of way for wagon roads in and across the reserves; for granting rights of way for irrigating ditches, flumes, and pipes, and for reservoir sites; and for permitting prospectors to enter the reserves in search of valuable minerals; for opening the reserves to the location of mining claims under the general mineral laws; and for allowing the owners of unperfected claims or patents, and the land-grant railroads with lands located in the reserves, to exchange them under equitable conditions for unreserved lands.

(3) That a bureau of public forests shall be established in the Department of the Interior, composed of officers specially selected with reference to their character and attainments, holding office during efficiency and good behavior and liberally paid and pensioned.

(4) That a board of forest lands shall be appointed by the President to determine, from actual topographical surveys to be made by the Director of the Geological Survey, what portions of the public domain should be reserved permanently as forest lands and what portions, being more valuable for agriculture or mining, should be open to sale and settlement.

(5) That all public lands of the United States more valuable for the production of timber than for agriculture or mining shall be withdrawn from sale, settlement, and other disposition and held for the growth and sale of timber.

(6) That certain portions of the Rainier Forest Reserve in Washington and of the Grand Canyon Forest Reserve in Arizona shall be set aside and governed as national parks.

Yours, respectfully, Charles S. Sargent, Henry L. Abbot, A. Agassiz, Wm. H. Brewer, Arnold Hague, Gifford Pinchot, Wolcott Gibbs.

To the President of the National Academy of Sciences.

2. *National Academy of Sciences: Washington Meeting.*—The following is a list of the papers presented at the meeting of the Academy held at Washington, April 19 to 22.

A. AGASSIZ: The coral reefs of Fiji.
A. AGASSIZ and W. McM. WOODWORTH: The Fiji bololo.
A. AGASSIZ and A. G. MAYER: The acalephs of Fiji.
J. S. BILLINGS: The variation in virulence of the Colon bacillus.
THEO. GILL: Biographical memoir of Edward D. Cope.
ALPHEUS HYATT: New classification of Nautiloidea.
A. A. MICHELSON: A new spectroscope.
IRA REMSEN and E. E. REID: On the hydrolysis of acid amides.

IRA REMSEN and W. A. JONES: The question of the existence of active oxygen

IRA REMSEN and J. W. LAWSON: On the product formed by the action of benzenesulphonchloride on urea.

IRA REMSEN: On double halides containing organic bases.

W. K. BROOKS: McCrady's Gymnopthalmata of Charleston harbor.

CARL BARUS: Ballistic galvanometry with a countertwisted torsion system. A curious inversion in the wave mechanism of the electromagnetic theory of light.

CHARLES S. HASTINGS: A consideration of the conditions governing apparatus for astronomical photography.

T. C. MENDENHALL: The use of graphic methods in questions of disputed authorship, with an application to the Shakespeare-Bacon controversy.

A. W. WRIGHT: A method for obtaining a photographic record of absorption spectra.

H. Y. BENEDICT: Theories of latitude variation.

E. W. BROWN: Progress in the new theory of the moon's motion.

CHARLES L. DOOLITTLE: On the variation of latitude and the aberration-constant.

The next meeting of the Academy will be held at New Haven, Conn., on November 15th.

3. *American Association for the Advancement of Science.*— The fiftieth anniversary of the Association will be celebrated at the coming meeting in Boston, August 22 to 27. A preliminary circular has been recently distributed giving the names of the officers of the meeting, of the local committee and also the plans so far as matured for giving this meeting the importance which the occasion demands. The sessions are to be held in the halls and rooms of the Massachusetts Institute of Technology and of the Boston Society of Natural History; accommodations will be thus furnished for all the Sections and for the General Sessions in three closely adjoining buildings. It is also stated that the Corporation of Harvard University has invited the Association to be its guest for a day in Cambridge: and that the Essex Institute has arranged for a day in Salem. There will also be an excursion in the harbor, and after the meeting, trips to the White Mountains and to Cape Cod. Many foreign scientists will be invited to take part, and many foreign educational and scientific institutions are expected to send delegates, thus giving to the meeting an international character. During the Association week and the days immediately preceding, a number of affiliated societies will meet in Boston including the American Geological Society, the American Chemical Society, the Society of Economic Entomologists, and others.

The President of the meeting is Prof. F. W. Putnam, who for twenty-five years has performed the laborious duties of Permanent Secretary. In retiring from this position he makes an earnest appeal to all interested in science to take hold and make this anniversary meeting thoroughly successful. This call will doubtless meet with a generous response. All correspondence should be addressed to the Local Secretary, Prof. H. W. Tyler, Massachusetts Institute of Technology, 491 Boylston st., Boston.

4. *Science Abstracts. Physical and Electrical Engineering.*— The Institution of Electrical Engineers and the Physical Society of London have recently undertaken the publication of a monthly series of abstracts in their departments of science. This appears to be an extension of the work hitherto done by the Physical Society and published in their Proceedings. The editor-in-chief is J. Swinburne and the sub-editor W. R. Cooper. The committee includes Capt. Abney, Profs. W. E. Ayrton, A. W. Rücker, S. P. Thompson, and others, and a list of about forty abstractors is given. Part 3, volume I, for March, 1898, is now in hand and gives abstracts from No. 231 to 355. It is obvious that it is a great advantage to all interested in science to have placed before them a brief, well-written digest of memoirs recently published in the many scattered journals and society transactions, and it is to be hoped that the enterprise may receive the full support it deserves.

OBITUARY.

Prof. JULES MARCOU, the veteran geologist, died at his home in Cambridge, Mass., on April 17th at the age of seventy-four years. He was born in Salins, Jura, France, April 20, 1824, and was educated at Besançon and afterward at Paris. In 1845 he became associated with Jules Thurmann, in his work on the geology of Jura Mountains; it was while engaged in this that he first met Louis Agassiz, with whom he later became intimate. Acting as traveling geologist for the Jardin des Plantes, he visited the United States and Canada in 1847 and accompanied Prof. Agassiz on his trip to the Lake Superior region in 1848. The collections of minerals he then made were forwarded to Paris in the following year. Later he studied the geology of New Jersey, Pennsylvania, Virginia and the Mammoth Cave. After a short visit to Europe, in 1850, he returned to this country and published his geological map of the United States and the British North American possessions. Entering the geological service of the United States in 1853, he made a section map of the thirty-fifth parallel from the Mississippi River to the Pacific Ocean. His impaired health compelled a return to Europe in 1855, and from that year to 1859 he held a professorship in the Polytechnic School in Zurich. In 1861 he returned to the United States and aided Prof. Agassiz in the founding of the Museum of Comparative Zoology, in which he had charge of the paleontological division. From 1864 on he devoted himself to scientific work, and in 1875 he again entered the National service for a time. Prof. Marcou was decorated with the Cross of the Legion of Honor in 1867, and was a member of many scientific societies here and abroad. He published numerous works on scientific, geological and geographical subjects, both in this country and France. His last work of note was a a life of Agassiz, published in 1896. Many of his papers in recent years have been largely of a polemical nature. He was positive and vigorous in controversy and persistent in his opinions. The debatable questions on the Taconic and Jurassic furnished him with many themes for defense and attack.

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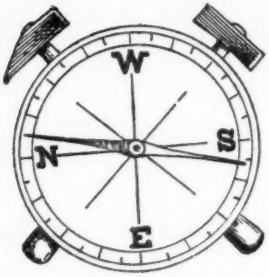

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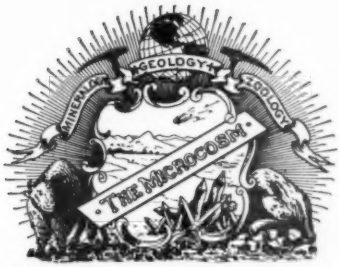

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(1) Described in this Journal Sept., 1895. (2) Ibid Nov., 1887. (3) Proc. Roch. Acad. Sci. Vol. 1. (4) This Journal Aug., 1888. (5) Ibid July, 1893. (6) Ibid June, 1894.

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